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Mineral Resources of the Waynesboro Quadrangle Tennessee

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STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
Wilbur A. Nelson, State Geologist

BULLETIN 26

Mineral Resources of the Waynesboro Quadrangle Tennessee

By HUGH D. MISER

NASHVILLE, TENNESSEE
1921

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Williams—Nashville

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One of the two natural bridges at "The Courthouse" near Fortyeight Creek, 5 miles southwest of Allens Creek. Looking northwest at the west bridge. The Osgood limestone of Silurian age forms the lower part of the abutments and the Laurel limestone of the same age forms the arch and the upper part of the abutments.

Mineral Resources of the Waynesboro Quadrangle, Tennessee

By Hugh D. Miser

Work Done in Cooperation with the United States Geological Survey.

LOCATION

The Waynesboro quadrangle embraces 974 square miles lying a little west of south-central Tennessee (see Fig. 1) and extending from latitude 35° on the south to 35° 30′ on the north and longitude 87° 30′ on the east to 88° on the west. It includes all of Wayne County, except two small areas in the northwest corner and also includes narrow strips of Hardin, Decatur, Perry, Lewis and Lawrence counties, Tenn. and a narrow strip of Lauderdale County, Ala., (see Plate I in pocket). The name is derived from Waynesboro, the county seat of Wayne County.

PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

The field work of this report was done in the summer and fall of 1913, the fall of 1914 and the spring of 1920 as the result of a co-operative agreement between the State Geological Survey and the United States Geological Survey. The field work was done by the writer but in 1913 he was assisted by N. F. Drake, ex-State Geologist of Arkansas, Bruce Wade, Assistant Geologist of the Tennessee Geological Survey and Olaf P. Jenkins who was at that time a member of the Tennessee Geological Survey. The writer is especially indebted to these gentlemen for their efficient assistance. Since 1913 Wade and Jenkins did much field work in central Tennessee to obtain data for use in the compilation of the geologic map of the State that was published in 1915, and they kindly furnished the writer numerous notes on the lower Mississippian rocks in that part of the State and also prepared for him a map illustrating certain features of their distribution. Wade, who has made a comprehensive study of the Cretaceous rocks of West Tennessee and of the terrace deposits along Tennessee River in this part of the State, has on several occasions conferred with the writer on problems that relate to the Tuscaloosa gravel in the Waynesboro quadrangle.

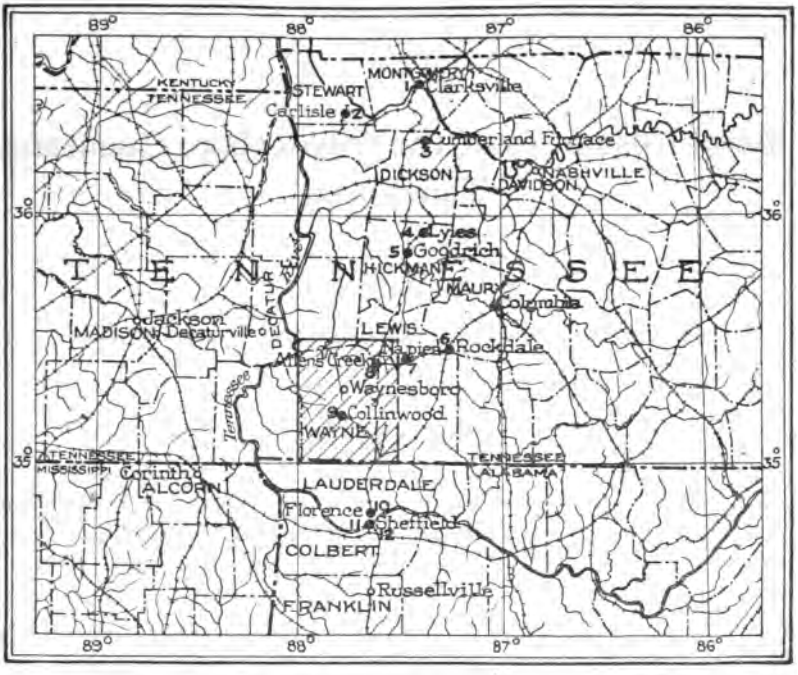

FIGURE 1.—Index map of west-central Tennessee, northwest Alabama, and northeast Mississippi showing the location of the Waynesboro quadrangle, and the location of the blast furnaces.

1. Helen Furnace, Clarksville, Tenn. 2. Dover Furnace, Carlisle, Tenn. 3. Cumberland Furnace, Cumberland Furnace, Tenn. 4. Wrigley Furnace, Lyles, Tenn. 5. Goodrich Furnace, Goodrich, Tenn. 6. Rockdale Furnace, Rockdale, Tenn. 7. Napier Furnace, Napier, Tenn. 8. Mannie Furnaces (two stacks), Allens Creek, Tenn. 9. Anna Furnace Collinwood, Tenn. 10. Philadelphia Furance, Florence, Ala. 11. Hattie Ensley furnaces (two stacks), Sheffield, Ala. 12. Sheffield Furnace, Sheffield, Ala.

Most of the analyses of rock specimens and many of the analyses of ore of different kinds were made by Paul C. Bowers, who was formerly chemist for the State Geological Survey. Mineral analyses of waters from the Waynesboro quadrangle have been made by Margaret D. Foster, of the U. S. Geological Survey and W. D. Collins of that Survey has furnished statements regarding the quality of the waters as indicated by the analyses.

Acknowledgment is due to Arthur Keith of the U. S. Geological Survey and the late Dr. A. H. Purdue, of the State Geological Survey for their co-operation in the field and office; to G. H. Girty of the U. S. Geological Survey for assistance in stratigraphic problems in the field and office and for study of Carboniferous fossils; to E. O. Ulrich of the U. S. Geological Survey for assistance in stratigraphic problems and study of Ordovician, Silurian and Devonian fossils; and to Warren R. King of the U. S. Geological Survey for preparing the chapter on water-power possibilities. Acknowledgement is also due the officials of the mining companies for information and to the people living in the Waynes-

boro quadrangle for their uniformly courteous treatment. Among these are E. L. Lull of Iron City, Tenn.; Thomas S. Bailie and R. W. Durrett of Collinwood, Tenn.; G. W. Boyd of Waynesboro, Tenn.; A. E. Boyd of West Point, Tenn.; and Daniel King of Russellville, Ala.

A preliminary report entitled, "Economic geology of the Waynesboro quadrangle" has been prepared by N. F. Drake and was published by the State Geological Survey in 1914[1]. For this report the present writer supplied many additions including the table of rock formations and the descriptions of the formations. The writer has prepared a note[2] on two natural bridges on Fortyeight Creek, 5 miles southwest of Allens Creek and has prepared a report on the structure of the Waynesboro quadrangle with special reference to oil and gas[3]. Both of these were published by the State Geological Survey. The manuscript map of the quadrangle was used by the State Geological Survey in the preparation of the geologic map of Tennessee that was published in 1915. The preparation of the present report and also that of the Waynesboro folio have been delayed by a number of exigencies, chief of which were (1) the necessity for the completion of other reports that had been begun before the Waynesboro investigation was begun and (2) urgent work in connection with the World War.

GEOGRAPHY

The Waynesboro quadrangle is situated in the western part of the physiographic division of the State, known as the Highland Rim, which is a dissected plateau that stands above and surrounds the Nashville Basin in the center of the State, and which is bordered on the west by the Mississippi Embayment of the Gulf Coastal Plain.

The part of the Highland Rim Plateau thus included in the Waynesboro quadrangle is so extensively dissected that there is but little level upland, which occurs in greatest amount at and near St. Joseph, Ovilla, and Collinwood and in the southwestern part of the quadrangle. The ridges which occur in most parts of the quadrangle are narrow and crooked and they have flat-topped crests which are remarkably uniform in height as is shown in any skyline view across the country. The former plateau surface thus marked by the crests of the ridges is roughly domelike in form with its greatest elevations in the central and east-central parts of the quadrangle where some elevations slightly exceed 1,050 feet above sea level. From these parts of the quadrangle the plateau surface slopes gently to the north, west and south until along the borders of the quadrangle in these directions the greatest elevations range from about 750 to 950 feet above sea level.

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[1]Drake, N. F., Economic geology of the Waynesboro quadrangle: The Resources of Tennessee, vol. 4, pp. 99-120, 1914.

[2]Miser, H. D., Two natural bridges of Tennessee: The Resources of Tennessee, vol. 4, pp. 136-138, 1914.

[3]Structure of the Waynesboro quadrangle with special reference to oil and gas: The Resources of Tennessee, vol. 7, pp. 199-219.

The quadrangle is drained by Tennessee River and some of its small tributaries, though only parts of two bends of the Tennessee enter it in the northwest corner. Before the Tennessee reaches the quadrangle it flows in a west by north course across northern Alabama several miles south of the quadrangle; thence it makes a sweeping curve flowing to the northwest, then to the north past Savannah, Tenn., and next to the northeast into the quadrangle at Clifton and Peters Landing; and after leaving the quadrangle it takes a northward course into Kentucky where it enters the Ohio.

The more important tributaries of Tennessee River in the area under discussion are Buffalo River, which crosses the northern part, Indian and Hardin creeks, which rise near the center of the area and leave it on the west side, and Shoal Creek, which crosses the southeast corner. Each of these as well as smaller tributaries receives the waters of a number of streams, so that the entire number of streams is very great. Many of these streams, including Indian and Hardin creeks, rise within a few miles of Collinwood, near the center of the quadrangle and flow in a general radial direction to and across its boundaries.

There is a marked relation between the drainage and the structure of the rocks, but this is discussed on page 41.

The streams are characterized by rather narrow valleys 100 to 300 feet deep which are bordered by the steep slopes of the intervening ridges. The elevation of most of the valleys ranges from 500 to 750 feet above sea level, but the lowest valley, that of Tennessee River, is between 300 and 350 feet above sea level. Narrow stream flats occur along the rivers and larger creeks and even along many of the smaller ones. These have a fertile soil and afford most of the tillable land of the quadrangle. The streams are perennial and are clear between heavy rainfalls and they furnish an ample water supply for washing the brown iron ores that occur on or near the crests of many of the ridges. When the iron-ore washing plants at and near Allens Creek, Pinkney, Iron City, Hardwick and Corning are in operation much red clay is emptied into the streams rendering them muddy but large quantities of the clay are caught in settling ponds that are built for this purpose.

The streams formerly had many deep holes along their courses, but within the last 30 or 35 years most of them have been gradually filled up by gravel that has been washed into them. Not only have these holes been filled up but other parts of the stream beds through most of their courses have been partly filled with gravels. The numerous gravel bars along the streams have also been enlarged, and much fertile soil has been eroded from fields along the streams. These conditions have been caused by the considerable amount of erosion that has resulted from the gradual deforestation and improper cultivation of the steep hillslopes.

Numerous springs, large and small, afford a supply of clear pure water in most parts of the quadrangle. The underground drainage

supplying them has formed extensive channels including caves in the limestone, which is more abundant than other kinds of rocks. Such a channel, through which a small tributary of Fortyeight Creek runs, passes through a hill 5 miles southwest of Allens Creek and may therefore be called a tunnel. The tunnel has been enlarged not only by the solution of the limestone in which it occurs but also by the falling in of limestone blocks from the roof and sides. The roof over much of the tunnel has completely caved in and the two parts of the roof that remain form two natural bridges. The east bridge has a span varying from 20 to 30 feet; an arch of 22 feet, and a width of more than 60 feet; the west bridge (see Plate II) has a span of 25 to 30 feet, an arch of 28 feet where the small stream flows from beneath it, and a width of 45 feet. The spacious roomlike openings beneath the arches are known locally as "The Courthouse." A fuller description of the bridges is given in Volume 4, No. 3 of the Resources of Tennessee.

Owing to the occurrence of most of the tillable land along the streams and to the constant supply of water along them the inhabitants live for the most part on or near streams. This has necessitated the naming of the streams or their valleys whereas very few if any of the ridges on which a small number of houses are located have been given names.

The quadrangle is sparsely populated though all parts of it are inhabited. The rural residents, most of whom are engaged in agriculture and lumbering, live chiefly in the valleys where the most fertile land occurs and where as a rule water is most accessible and abundant. The largest towns are Iron City, St. Joseph, West Point, Collinwood, Clifton, and Waynesboro, the last of which is the county seat of Wayne County.

The Columbia, Florence & Sheffield Branch of the Louisville & Nashville Railroad traverses the southeast corner of the quadrangle passing through St. Joseph and Iron City. Another branch of the railroad runs from Iron City through Wayland Springs and West Point to Pinkney. The Tennessee Western Railroad runs from Iron City to Collinwood; and a railroad from Collinwood to Wayne Furnace is now under construction. The Centerville Branch of the Nashville, Chattanooga & St. Louis Railway enters the northeast corner of the quadrangle and extends as far as Allens Creek. Transportation along Tennessee River is carried on by means of steamers and gasoline launches but a large quantity of timber is floated down stream in rafts. All parts of the quadrangle are reached by public roads, most of them in poor condition. Many of the roads pass through areas where gravel and chert are the surface rocks and in such areas parts of them have good surfaces, although they are worked but little or not at all. A macadamized pike with toll-gates is maintained between Clifton and Waynesboro, and the Jackson Military Highway with a macadamized surface runs northeastward through St. Joseph. In April, 1920, plans were being made to macadamize the Waynesboro-Lawrenceburg Road.

The chief occupations in the quadrangle are mining, lumbering, and agriculture. The quadrangle is especially adapted to general farming, fruit growing and grazing. There are a number of limestone quarries and some flint quarries, but brown iron ore is the chief mineral product that is mined. Iron ore mines that are or have been operated are located at or near Riverside, Allens Creek, Furnace Branch, east by north of Waynesboro, Pinkney, West Point, Hardwick, Corning, Wayland Springs, Iron City and Clifton. Two blast furnaces known as Mannie Furnace No. 1 and Mannie Furnace No. 2 are located at Allens Creek, and another known as Anna Furnace is located at Collinwood. Furnaces that were operated many years ago are Wayne Furnace on Furnace Branch, Van Leer Furnace on Butler Creek, west of Iron City and Marion Furnace 2 miles south of Clifton. Lumber mills including planing mills, stave mills, spoke factories, and saw mills are common. Large quantities of railroad ties and telephone and telegraph poles are shipped. There are a few flour mills, a few cotton gins, and many grist mills. Some of the small mills are run by waterpower.

GEOLOGY

ROCK FORMATIONS

GENERAL FEATURES

The rocks of the Waynesboro quadrangle are all of sedimentary origin and consist predominantly of limestone, though beds of shale, chert, sandstone, gravel, and sand are present. They are of Ordovician, Silurian, Devonian, Carboniferous, Cretaceous and Quaternary age. The exposed rocks in this area are graphically represented in the columnar section in figure 2 on page 16. They belong to sixteen different formations which aggregate in maximum thickness 2,367 feet; of these only seven are everywhere persistent, whereas most of the other nine are cut out by unconformities over larger or smaller areas. The formations are briefly described below in the order of their age, with the oldest first. Detailed descriptions of them will be given in the Waynesboro folio to be published later by the United States Geological Survey.

ORDOVICIAN SYSTEM

CARTERS AND OLDER LIMESTONE

The Carters and older limestones are not exposed in the quadrangle, but were penetrated in one well at Iron City to a depth of 15 feet, in another well at that place to a depth of 509 feet, and in a well at Collinwood to a depth of about 806 feet. The cuttings of these limestones from these wells, of which records are given on pages 33 to 37, consist almost entirely of compact very fine-grained limestone which breaks with a conchoidal fracture and shows the following colors: bluish, whitish, light gray, dark gray, dove and cream. Traces of gas were found in three beds of these limestones at Iron City and traces of oil were also found in two beds of them at that place. A complete set of cuttings from the Collinwood well is not available. It is possible that this well passed into the Knox Dolomite.

HERMITAGE FORMATION

The Hermitage formation is exposed only in the northwest part of the quadrangle. Exposures occur on Beech Creek near Mooney; on Ross, Whiteoak, and Eagle creeks; on a tributary of Little Beech Creek; on the right bank of Tennessee River at Clifton; at and near Glenkirk; and just north of Lego. The Hermitage is the oldest exposed formation in the quadrangle and at no place has its base been revealed. The thickest exposure which comprises 80 feet of the upper part of the formation is near Mooney. Two deep wells at Iron City, of which records are given on pages 31 to 35, passed through the formation into the underlying Carters limestone and show its thickness there to be about 126 feet. The formation consists of about equal quantities of limestone

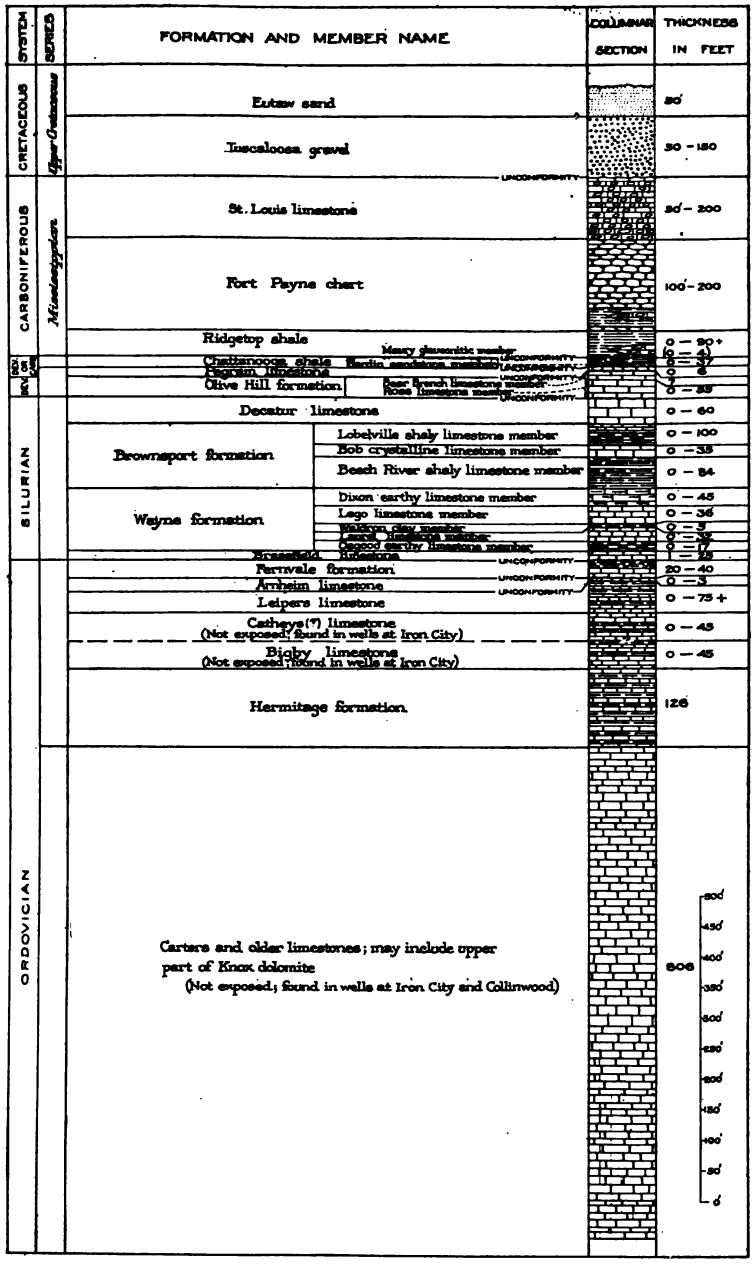

FIGURE 2.—Preliminary generalized section of the rocks of the Waynesboro quadrangle, Tennessee.

and shale the layers of which alternate with marked regularity (see Plate XIII, B). The limestone is brittle, dark bluish gray, slightly phosphatic, and fine-grained and is in even-bedded layers commonly 2 to 6 inches thick. An analysis of the limestone is given on page 19. The shale is dark colored and fissile.

The formation has yielded a small quantity of gas in the deep wells at Iron City, and limestone in the formation was used at Clifton in the manufacture of cement before and since the Civil War. These subjects are discussed more fully under the headings "Oil and Gas" (Page 147), and "Cement rock" (Page 124). The occurrence of phosphate rock in the residual clay of the Hermitage on Eagle Creek is described on page 139.

BIGBY LIMESTONE

The Bigby limestone is not exposed at any place in the quadrangle but has been found in deep wells at Iron City; it is absent in the northwest part of the quadrangle. The cuttings from the wells at Iron City show that it consists mostly of limestone, but partly of shale. The limestone is fine grained, fossiliferous, and somewhat sandy, and is usually gray though part of it is brown. The shale is dark colored and calcareous.

The Bigby comprises at least 45 feet of beds overlying the Hermitage formation at Iron City and fossils from the well cuttings at that place are said by E. O. Ulrich to indicate that it probably comprises still higher beds which are as much as 45 feet thick, and which are included in the Catheys (?) limestone. The total thickness of the formation is therefore probably 90 feet.

A small amount of gas was found in the Bigby limestone in a deep well at Iron City. This subject is discussed more fully on pages 30 and 148.

CATHEYS LIMESTONE

The Catheys Limestone is not exposed at any place in the quadrangle, nor is it known to be present under cover at any place. There is, however, a possibility that a part or all of the 45 feet of limestone and shale found in the wells at Iron City above the Bigby limestone may be the Catheys limestone. This limestone is fine grained and fossiliferous, and is mostly gray, but partly brown in color, and the shale is dark colored.

LEIPERS LIMESTONE

The Leipers limestone is exposed in a small dome-shaped anticline on Shoal Creek between Wayland Springs and the confluence of Factory Creek with Shoal Creek, where 75 feet of the limestone is exposed without revealing the base. It consists of dark-bluish fossiliferous slightly phosphatic limestone and a less though considerable amount of brown

shale. It was passed through by deep wells at Iron City, it being about 58 feet thick in one well and about 59 feet in another well, though some of the underlying limestone beds which are provisionally included in the Catheys (?) limestone may be a part of the Leipers limestone. The Leipers is absent in the northwest part of the quadrangle.

ARNHEIM LIMESTONE

The Arnheim limestone is cherty, gray, fossiliferous limestone. The only known exposure in the quadrangle is in the bluff at the landing at Clifton where it varies in thickness from a feather edge to 3 feet.

FERNVALE FORMATION

[The Tennessee Geological Survey feels that from Tennessee evidence the Fernvale formation should be considered as of Silurian age. This conclusion is based on the following facts: It is very similar in lithology to the Silurian hematitic ore bearing beds of the Birmingham, Alabama district, and as stated is the great bedded hematite ore bearing formation of Tennessee; it is the greatest overlapping formation in Tennessee in pre-Devonian times; and furthermore the fossil evidence, according to several of the leading paleontologists of America, proves this formation to be of Silurian age.—W. A. N.]

The Fernvale formation is exposed along Tennessee River and many small streams in the northwest part of the quadrangle where its largest outcrops occur. In the other parts of the quadrangle it is exposed along Rockhouse Creek at and near Nancy; on Buffalo River, 3½ miles west of Fortyeight Creek; on Buffalo River, near Riverside; on Blowing Spring Branch; on Duggar Branch; and along Shoal Creek from Iron City to the confluence of Factory Creek with Shoal Creek.

The formation varies from 20 to 40 feet in thickness and consists of two nearly equal parts, the lower part being limestone and the upper shale. The limestone is light-gray, coarsely crystalline and cross bedded and contains some phosphate in small disseminated grains. The residual clays at some places in the northwest part of the quadrangle contain considerable phosphate and they may be of future commercial importance though none of them have yet been prospected. The occurrences of the phosphate-bearing clays are described on pages 135 to 141. The shale comprising the upper part of the formation is soft, green in color, and fissile or platy and at places contains layers of fossiliferous limestone.

SILURIAN SYSTEM

BRASSFIELD LIMESTONE

The Brassfield limestone is the surface rock at a great many places in the northern half of the quadrangle and along Shoal Creek in the southeast corner. The outcrops are narrow bands along the streams

and probably at no place do they occur more than 100 feet above the beds of the streams. The limestone ranges in thickness from 1 to 25 feet. It is finely crystalline and light-gray, is in thin layers of uniform thickness, and contains many small green grains of glauconite. Two analyses of the limestone are given on page 19. There is at places at the base a massive coarsely crystalline light-gray limestone; at other places a conglomerate and at others a sandy ferruginous limestone.

The Brassfield limestone at Iron City is brown and contains 17 per cent of metallic iron. The limestone here averages about 4 feet thick and has been mined and used as a flux with the brown iron ores from Pinkney. This bed is fully described on page 127.

Analyses of limestones in the Waynesboro quadrangle

A. Limestone from the Hermitage formation. Clifton. Paul C. Bowers of Tennessee Geological Survey, analyst.

B. Brassfield limestone. Bluff on Tennessee River just northwest of Glenkirk. Paul C. Bowers of Tennessee Geological Survey, analyst.

C. Brassfield limestone. Near school house three-fourths mile north-northeast of confluence of Morrison Creek with Beech Creek. Paul C. Bowers of Tennessee Geological Survey, analyst.

D. Laurel limestone. Just east of boat landing at Clifton. Paul C. Bowers of Tennessee Geological Survey, analyst.

E. Laurel limestone. Cedar Point one-fourth mile north of Iron City. Paul C. Bowers of Tennessee Geological Survey, analyst.

F. Laurel limestone. Quarry one-fourth mile south of Riverside. R. K. Bailey of U. S. Geological Survey, analyst.

G. Lego limestone. Cedar Point one-fourth mile north of Iron City. Paul C. Bowers of Tennessee Geological Survey, analyst.

H. Lego limestone. Southeast part of Clifton. Paul C. Bowers of Tennessee Geological Survey, analyst.

	A	B	C	D	E	F	G	H
Silica (SiO_2)	14.19	2.28	1.60	4.78	3.40	1.32	5.50	3.20
Alumina (Al_2O_4)	2.95	.60	.77	1.89	1.88	.92*a*	2.19	1.42
Ferrous oxide (FeO)	.38	.31	.33	.03	.28	....	.18	.23
Ferric oxide (Fe_2O_3)	.21	1.02	1.29	.48	.41	(*b*)	.37	1.00
Manganese oxide (MnO)	.....	....	.....	.47	.17	.....	.....	.....
Lime (CaO)	44.40	52.80	53.14	50.42	50.92	49.64	49.38	52.16
Magnesia (MgO)	.50	.70	.32	1.04	1.14	4.80	1.42	.34
Soda (Na_2O)	.48	.24	.38	.42	.34	.....	.54	.28
Potash (K_2O)	.66	.30	.22	.52	.44	.....	.62	.34
Phosphorus pentoxide(P_2O_5)	.57	.46	.45	....	.07	.....	.13	.10
Sulphur (S)	.....	....	.06	trace	.....	.....	.....	trace
Sulphur trioxide (SO_3)	.85	.02	.13	trace*c*	.45	.....	.07	trace
Carbon dioxide (CO_2)	34.30	41.04	41.30	39.54	40.34	43.90	39.30	40.79
Water at 100° C.	.25	.11	.10	.23	.19	.....	.25	.11
	99.74	99.88	100.09	99.82	100.03	100.58	99.95	99.97

*a*Includes (Fe_2O_3).
*b*Included in (Al_2O_3).
*c*Also a trace of (SO_4).

WAYNE FORMATION

The Wayne formation consists almost entirely of limestone, a very small part being clay. The beds of which the formation is composed have been separated by different geologists into a number of units, designated as formations, and named in ascending order, Osgood limestone, Laurel limestone, Waldron shale, Lego limestone, and Dixon formation. These units, however, are thin, none being more than 45 feet thick at any place, and they can not therefore be mapped separately on the Waynesboro topographic map, but have been mapped together, under the name Wayne formation, the different parts being called members. The names of these members as here used are Osgood earthy limestone member, Laurel limestone member, Waldron clay member, Lego limestone member, and Dixon earthy limestone member.

The formation is exposed along Buffalo, Green, and Tennessee rivers and along Indian, Hardin, Eagle, Beech, Whiteoak, Fortyeight, and Shoal creeks, and their small tributaries in the west-central and northern parts of the quadrangle but is nowhere exposed in the southwest part. The outcrops occur in most places as narrow belts either in steep slopes or in bluffs near the bases of the hills. The formation is characterized by a remarkably even and regular bedding that contrasts conspicuously with the thickening and thinning of the beds of the succeeding Brownsport formation. During a post-Silurian erosion interval it suffered excessive erosion with the result that the upper members are less widely distributed than the lower ones. Exposures of all of the members may, however, be found in the west-central, northern and southeastern parts of the quadrangle, except the Dixon limestone which is not known to occur in the southeastern part. The different members are always present except in such places as those where they were truncated by post-Silurian erosion. Their thicknesses as given below do not include measurements of the truncated edges of the members, but only those that were made at places where the various members are overlain by higher Silurian rocks.

The Osgood limestone consists mostly of thin-bedded earthy limestone but contains one or two layers of pure limestone 12 inches or less thick. The earthy limestone is red in the vicinity of Clifton and Iron City, but elsewhere is gray. The member ranges in thickness from 10 to 17 feet.

The Laurel limestone is composed of compact pinkish and bluish-gray limestone, in both thin and massive layers, and ranges in thickness from 19 to 32 feet. Three analyses of this limestone are given on page 19. The bridges at "The Courthouse" 5 miles southwest of Allens Creek have been formed in the Laurel and Osgood limestones, (see Plate II).

The Waldron clay member is a fossiliferous, indurated gray, though less often pink, clay near the middle of which there is a thin persistent

layer of hard gray limestone. The member ranges in thickness from 2½ to 5 feet, the maximum occurring in a quarry just south of Mannie furnaces at Allens Creek.

The Lego limestone is composed of compact pinkish and bluish-gray limestone closely resembling that in the Laurel member. It varies in thickness from 25 to 36 feet and the layers from a few inches to 2 feet. Two analyses of it are given on page 19.

The Dixon member is an earthy limestone that is red in the vicinity of Clifton, but east and southeast of that place it loses its red color and is greenish gray in color. The thickness ranges from 10 to 45 feet.

BROWNSPORT FORMATION

The Brownsport formation is exposed along the streams in the northern and western parts of the quadrangle, but is absent in other parts of the quadrangle. It consists mainly of shaly limestone and massive crystalline limestone which are comprised into three members, the Beech River shaly limestone member at the base, the Bob crystalline limestone member in the middle part, and the Lobelville shaly limestone member at the top. The thicknesses of the members as given below vary from place to place, but they as a rule thin out to the east with the lower beds extending farthest in this direction, the upper ones having been planed off by post-Silurian erosion. This formation contains an abundance of well-preserved fossils and the glades produced by the beds of shaly limestone have made this part of the State famous for fossil collectors.

The Beech River member is extensively exposed in the west-central and northwest parts of the quadrangle and it is present at some places in the northeast part; but it is absent in the southeast part. It is composed mostly of shaly fossiliferous cherty, greenish-gray or yellowish-gray and pink limestone but partly of fossiliferous greenish and purplish shales. It ranges in thickness from a feather edge to 84 feet.

The Bob limestone member is present and is widely exposed in the west-central and northwestern parts of the quadrangle but is absent at most places in the northern part and at all places in the southeastern part. It forms a low bluff along much of its outcrop. It consists mainly of a massive, coarsely crystalline, light-gray fossiliferous limestone but at places it contains thin-bedded cherty limestone. The thickness ranges from a feather edge to 35 feet.

The Lobelville limestone member is exposed at many places in the west-central and northwest parts of the quadrangle but is absent in the northeast and southeast parts. At most places it is composed of gray shaly limestone and yellowish shale. Corals of many kinds are the most abundant fossils. The member ranges in thickness from a feather edge to about 100 feet.

DECATUR LIMESTONE

The Decatur limestone is present and is exposed at a considerable number of places in the west-central and northwest parts of the quadrangle but is absent at most places in these parts of the area as well as at all places in the northeast and southeast parts. It is a massive light-gray to bluish-gray coarsely crystalline to fine-grained limestone. Its thickness ranges from a feather edge to 60 feet.

DEVONIAN SYSTEM

OLIVE HILL FORMATION

The Olive Hill formation is present at only a few places in the Waynesboro quadrangle. The beds in the quadrangle which are included in this formation were described in previous papers by the writer[1], published in 1914 and 1917, as a part of the Linden formation, which is widely distributed in western Tennessee outside the quadrangle. For many years the name Linden formation has been applied by geologists to some of the rocks of Devonian age in West Tennessee, but in 1918 C. O. Dunbar[2] subdivided the Linden into two formations, and extended its limits both above and below, so that the Linden as defined by him is a group and comprises all the rocks of Helderberg age in western Tennessee. The formations of the Linden group as defined by him are as follows, named in the order of their age with the oldest first: Rockhouse shale; Olive Hill formation with the Ross, Bear Branch, and Flat Gap limestone members (oldest named first); Birdsong shale; and Decaturville chert. The beds to which Dunbar has applied the names Rockhouse shale and Decaturville chert were not included in the Linden by previous writers.

Of the rock formations of the Linden group as defined by Dunbar only the Olive Hill formation is present in the Waynesboro quadrangle, and only two of its three members are known to occur in the quadrangle; these two are the Ross and Bear Branch.

The Ross limestone occurs at a locality 2¾ miles north of Glenkirk, at the Sanders Mine 1½ miles south-southeast of Clifton, and in and near Hughes Hollow about 2 miles south of Clifton. The only exposures of the unaltered limestone are at the locality north of Glenkirk, where 9 feet of massive coarsely crystalline gray siliceous limestone are exposed, and in Hughes Hollow. The limestone is not exposed at the Sanders Mine but its silicified fossils are numerous in residual clays. In and near Hughes Hollow the unaltered limestone is mostly concealed by yellow fine-grained fossiliferous sandstone in thin slabs derived by weathering

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[1]Miser, H. D., in Drake, N. F., Economic geology of the Waynesboro quadrangle: The Resources of Tennessee, vol. 4, No. 3, pp. 100-105, July 1914.

Miser, H. D., Structure of the Waynesboro quadrangle with special reference to oil and gas: The Resources of Tennessee, vol. 7, No. 4, p. 201, Oct., 1917.

[2]Dunbar, C. O., Stratigraphy and correlation of the Devonian of western Tennessee: Am. Jour. Sci., 4th ser., vol. 46, pp. 732-756, Dec., 1918. Tennessee Geol. Survey Bull. 1919.

from the limestone. The thickness on the hill near the Hughes Spring in this hollow is apparently 55 feet.

The Bear Branch limestone so far as known is not exposed in the Waynesboro quadrangle, but Dunbar[1] concludes that the red iron-bearing clay at the Sanders Mine 1½ miles south-southeast of Clifton is residual from the Bear Branch limestone. The iron ore at this locality is largely hematite and occurs in irregular layers at some places and irregular masses at other places. Dunbar states that the unweathered limestone is coarse-grained, impure in parts but rather pure in other parts, and contains oolitic hematite. Brown iron oxide is present in the surficial residual materials just above the Ross limestone in and near Hughes Hollow about 2 miles south of Clifton and at a locality 2¾ miles north of Glenkirk. The Bear Branch limestone is not exposed at these localities but the presence of the masses of iron oxide suggest that it is present. These iron ores are described on pages 116 and 118.

PEGRAM LIMESTONE

The Pegram limestone is present in a small area on Mill Creek near Fortyeight. Two exposures were observed, one being in the bluff just west of the mouth of the creek where the limestone is 5 feet 8 inches thick and the other at a waterfall about one mile north of the mouth of the creek where it is 6 feet thick. So far as known these are the only exposures in the quadrangle. The limestone is gray, crystalline and crinoidal.

DEVONIAN OR CARBONIFEROUS SYSTEM

CHATTANOOGA SHALE

The Chattanooga shale with its basal part, the Hardin sandstone member, is widely distributed in the quadrangle and forms one of the most conspicuous horizons, though the formation is thin, the shale having a maximum of 22 feet and the sandstone 15 feet. The Hardin is a rather fine-grained phosphatic sandstone, commonly occurring as a massive ledge that produces a low vertical bluff. The overlying shale is coal black and platy and at many places contains thin phosphatic sandstone layers in its basal part; it is less widely distributed than the Hardin sandstone.

The age of the Chattanooga shale in the Waynesboro quadrangle as well as elsewhere has been the subject of much discussion for several years. It is either late Devonian or early Mississippian.

CARBONIFEROUS SYSTEM

(*MISSISSIPPIAN SERIES*)

RIDGETOP SHALE

The Ridgetop shale is widely exposed and is present at most places

[1]Dunbar, C. O., op. cit., pp. 44-45, 115.

in the northern and western parts of the quadrangle. In these parts it is gray and platy, and contains very few fossils; it increases in thickness from a feather edge to 90 feet toward the south and southeast and it also becomes calcareous, siliceous, and hard in these directions. Beds of apparently the same age are present in the southeast part of the quadrangle; they are green siliceous shale and thin and thick beds of gray coarse-grained crinoidal limestone in which there is generally some chert. Fossils are numerous in the limestone.

Thin beds of glauconitic sandstone and shale occur at the base and to these the term Maury glauconitic member is applied. This member is commonly, though not always, present. At most places it is a green sandstone and at others a green platy shale, both of which contain glauconite and nodules of dark-colored phosphate. The thickness of the member is usually a few inches but at places it is as much as 4 feet. Descriptions of it at several localities and analyses of phosphate-bearing rock in it at these several localities are given on pages 136 and 140.

FORT PAYNE CHERT

The Fort Payne chert is exposed on the hillslopes in all parts of the Waynesboro quadrangle, except in an area 10 miles square in which Cypress Inn is located. In the northwest half of the quadrangle it is composed of dark-gray calcareous chert that changes on weathering to a soft yellow platy porous chert, but it is composed in part of gray shale and compact dark bluish-gray flint, and in the southeast part of the quadrangle it contains massive and thin beds of gray cherty crinoidal limestone. The thickness of the entire formation ranges from 100 to 200 feet. In the central and southwestern parts of the quadrangle a bed at the top of the formation has changed on weathering to a soft fine-grained siliceous white material that is known as tripoli. Some of the tripoli deposits are described on pages 129 and 131. Some of the flint has been quarried near Iron City and St. Joseph for use as dimension blocks in lining tube mills. (See Plates XI, A and XIV, A). The developed deposits of flint are described on pages 132 and 134.

ST. LOUIS LIMESTONE

The St. Louis limestone has a greater surface distribution than any other formation. It caps the hills and ridges in all parts of the quadrangle except in the southwestern and central parts where the outcrops occur on the lower hillslopes. The whole formation is not present, much of it having been removed by erosion prior to Upper Cretaceous time, but the part still remaining generally ranges in thickness from 50 to 200 feet. The limestone is gray and usually contains much chert, but the unaltered limestone is exposed at only a very few places, all of which are in the northeastern, central, and southwestern parts of the quadrangle. At

most places it is concealed by a residual mantle as much as 100 feet thick, which consists of clay and angular fragments of fossiliferous chert.

Deposits of tripoli that have been derived from the weathering of siliceous beds at or near the base of the St. Louis limestone are described on pages 130 and 131.

CRETACEOUS SYSTEM

(*UPPER CRETACEOUS SERIES*)

TUSCALOOSA GRAVEL

The Tuscaloosa gravel occurs in the northern half of the quadrangle as a thin mantle, a foot or two to nearly 50 feet thick, capping most of the higher hills and ridges, but it thickens toward the southwest corner of the quadrangle where it is exposed over much of the highlands and reaches a thickness of 150 feet.

The formation consists almost entirely of gravel, but contains a small amount of clay and sand. The pebbles are fairly to well-rounded, they range in size from that of a pea to 4 inches in diameter and they consist almost entirely of chert pebbles which have been derived from the St. Louis and other cherty rocks in this part of the State. Much of the gravel, especially its lower part is cemented together by brown iron oxide, thereby forming a very hard conglomerate.

The Tuscaloosa gravel has been used for paving streets and for making concrete in Collinwood and has been used on the Clifton-Waynesboro pike a few miles west-northwest of Waynesboro. It is excellent material for both purposes and the quantity is so great as to be practically inexhaustible.

EUTAW SAND

The Eutaw sand overlies the Tuscaloosa gravel and caps the ridges in the southwest quarter of the quadrangle. Its greatest measured thickness is 50 feet. The sand is red but weathers at the surface to a gray color and at places it contains many horizontal layers of gray clay a fraction of an inch thick.

QUATERNARY SYSTEM

Terrace deposits occur as patches here and there at elevations of as much as 140 feet above the present streams and are composed of chert pebbles intermingled with and overlain by loam. Practically all the patches occur along Tennessee and Buffalo rivers. The most conspicuous of these, however, is the one on which the village of Flatwoods is located. These deposits were put down on the flood plains of the streams when they ran on the rocks on which the gravels lie, but subsequently the streams have cut their present valleys down below the level of these deposits, leaving the old stream flats as high terraces.

The alluvium is the most recent deposit of the quadrangle and consists of gravel and silt. It underlies the stream flats half a mile or les-

in width which occur along the larger and most of the smaller streams.

The gravel which occurs in large gravel bars along the streams has been used in road-building and in making concrete. It is well suited for both purposes, and the quantity along both the large and small streams is very great.

WELL RECORDS

The well records given below describe in detail the rocks that have been passed through by the deep wells of the quadrangle.

Record of Seavy-Lull Well No. 2, Iron City, Tenn.

(Engineer in charge, E. L. Lull; drillers, J. R. Wilson and F. P. Miller. Drilling begun December 11, 1914; well discontinued March 1, 1915. Elevation of top of well 565 feet above sea level.)

Age and formation			Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
Quaternary	Alluvium					0-8 feet, alluvium
SILURIAN	Wayne formation	Laurel limestone member	1	8–10	Finely crystalline, gray limestone with pink spots, making limestone pinkish gray	Very hard limestone
			2	10–12	Same as sample No. 1	
			3	12–14	Red and greenish, compact, somewhat earthy limestone	
		Osgood earthy limestone member	4	14–18	Red, compact, somewhat earthy limestone	Very hard, shaly, red limestone
			5	18–20	Same as sample No. 4	
			6	20–23		Very hard red limestone; cherty layers
			7	23–26		Very hard brownish limestone; so called spathite
	Brassfield limestone		8	26–29.5	Compact light-gray limestone with glauconite grains	Very hard, siliceous limestone; little or no iron
	Brassfield limestone or Fernvale formation		9	29.5–33	Red limestone	Soft, red shale
ORDOVICIAN	Fernvale formation		10	33–35	Buff, calcareous, argillaceous material, probably shale	Green shale, probably phosphatic
			11	35–37.5	Greenish-gray slightly phosphatic, sandy, argillaceous, highly calcareous material, probably impure limestone	Green shale
			12	37.5–39	Soft, calcareous, gray shale	
			13	39–44	Dark-gray, very impure limestone, containing much fine quartz sand	Green shale, probably arenaceous
			14	44–48	Slightly phosphatic, rusty, earthy limestone	Hard, brownish-yellow limestone
			15	48–51.5	Yellowish clayey, calcareous rock; probably shale with limestone streaks	
			16	51.5–55	Compact, light-gray, fossiliferous, slightly phosphatic limestone	Hard, gray limestone
			17	55–57	Light-gray, compact, Phosphatic limestone	

Age and formation		Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
ORDOVICIAN	Leipers limestone	18	57–62	Gray calcareous shale	Soft, blue limestone and clay
		19	62–65	Gray earthy, calcareous material, probably shale	Blue limestone
		20	65–70	Gray earthy, calcareous material. It is calcareous shale or very earthy limestone	Very hard blue limestone
		21	70–72	Gray fossiliferous, slightly phosphatic limestone and gray shale	
		22	72–75	No sample	Fairly hard, blue limestone; shaly layers
		23	75–90	Dark-gray shale and finely crystalline, slightly phosphatic, fossiliferous gray limestone	Fairly hard, blue limestone
		24	90–100	Slightly phosphatic, dark-gray compact, fossiliferous limestone	
		25	100–105	Drab-colored, calcareous shale, containing some gypsum	Very hard, blue limestone
		26	105–110	Dark-gray, slightly phosphatic, fossiliferous limestone, containing some clayey matter	
		27	110–115	Same as sample No. 26	
	Bigby limestone (?)	28	115–120	Light-gray, slightly phosphatic limestone and dark-gray arenaceous shale	Soft blue shaly limestone
		29	120–125	Same as sample No. 28; fossils examined by E. O. Ulrich, who reports them as "probably older than Catheys"*a*	Fairly hard, impure, blue crystalline limestone
		30	125–130	Fine-grained, dark-gray, slightly phosphatic, fossiliferous limestone containing some argillaceous matter	
		31	130–135	Brown, slightly phosphatic, fossiliferous, somewhat earthy limestone; grain of medium size	Fairly hard, yellowish fine-grained, fossiliferous, crystalline limestone
		32	135–139	Brown, slightly phosphatic, earthy material, may be earthy ferruginous limestone	Hard, yellowish, fine-grained, fossilferous, crystalline limestone

*a*The Catheys limestone where present in Tennessee is between the Bigby and Leipers limestones.

Age and formation	Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
ORDOVICIAN — Bigby limestone (?)	33	139–143	Gray, slightly phosphatic, fossiliferous limestone of medium grain; some material contains considerable clayey matter	Very hard, coarse, fossiliferous, crystalline, grayish limestone
	34	143–145.5	Like sample No. 35, except no fossils were seen	Very hard, fine-grained, crystalline, grayish limestone
	35	145.5–150	Light-gray, moderately crystalline, slightly phosphatic, fossiliferous limestone	
	36	150–154	Light-gray and dark-gray, moderately crystalline, slightly phosphatic, fossiliferous limestone	Very hard, coarse, crystalline, grayish limestone
	37	154–160	Dark-gray, finely crystalline, slightly phosphatic, fossiliferous limestone and some shale	Very hard, bluish limestone
	38	160–165	Dark-gray, slightly phosphatic, calcareous, fossiliferous shale. Fossils examined by Ulrich	Very hard, bluish limestone
	39	165–170	Dark-gray, finely crystalline, phosphatic, fossiliferous limestone and black shale. Fossils examined by Ulrich	Very hard, bluish limestone; probably arenaceous
	40	170–173	Dark-gray, finely crystalline, slightly phosphatic limestone and slightly calcareous black shale. Fossils examined by Ulrich	Very hard, probably arenaceous bluish limestone; trace of gas
	41	173–179	Limestone like that in sample No. 40. Fossils examined by Ulrich	Very hard, fine-grained crystalline, bluish limestone; trace of gas
	42	179–182	Dark-gray, finely crystalline, slightly phosphatic limestone and slightly calcareous, black shale. Contains some pyrite	Very hard, fine-grained, crystalline, bluish-gray limestone; trace of gas
	43	182–184	No sample	Very hard, fine-grained, crystalline, bluish-gray limestone containing pyrite. A strong flow of water highly charged with various salts, hydrogen sulphide, and probably natural gas. Estimated flow of
	44	184–189	Gray, slightly phosphatic, sandy pyritiferous limestone	

(over)

Age and formation		Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
ORDOVICIAN	Bigby limestone (?)	45	189–191	Slightly phosphatic, gray, sandy, pyritiferous limestone	water 500 gallons per hour rising 150 feet in well. Estimated flow of gas 5,000 cubic feet per 24 hours with rock pressure of about 20 pounds per square inch. Gas burns with bluish flame and gives off sulphur. From the well that was drilled 300 feet to the east I obtained several gallons of drillings that were washed in from the new well. This indicates that the flow of the water is to the east and opposite to the dip of the rocks
		46	191–193	Slightly phosphatic, gray, sandy limestone	
		47	193–198	Gray, slightly phosphatic limestone	
		48	198–205	Gray, slightly phosphatic limestone	
	Hermitage formation	49	205–205.7	Gray, calcareous shale	Soft, bluish-gray, shaly limestone*b*
		50	205.7-208.3	Gray, fossiliferous, fine-grained, slightly phosphatic limestone and gray shale	Hard, bluish-gray limestone
		51	208.3–210	Gray, sandy, pyritiferous, slightly phosphatic limestone	Hard, bluish-gray crystalline limestone
		52	210–215	Black, calcareous shale	Hard, bluish-gray, crystalline limestone
		53	215–219	Finely crystalline, dark-gray, slightly phosphatic, argillaceous, fossiliferous limestone	Very hard, bluish-gray limestone
		54	219–224	Same as sample No. 53 except no fossils were seen	Very hard, bluish gray limestone; trace of gas
		55	224–228		
		56	228–230	Finely crystalline, light-gray and dark-gray, argillaceous, slightly phosphatic limestone	
		57	230–234	Same as sample No. 56 but shows fossils	Very hard, bluish-gray limestone: trace of gas and black oil
		58	234–240	Same as samples Nos. 60 and 64, but shows fossils	
		59	240–242	Fine-grained, slightly phosphatic, argillaceous limestone	

*b*Drilling operations from the sulphur water down indicate a series of hard blue limestone beds of fairly uniform thickness separated by several inches of softer material.

Age and formation		Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
ORDOVICIAN	Hermitage formation	60	242–248	Same as sample No. 64	Very hard, bluish-gray limestone; trace of gas and black oil
		61	248–250	Calcareous, argillaceous material, probably all shale	
		62	250–255	Calcareous, gray shale	
		63	255–259	No sample	
		64	259–261	Fine-grained, dark-gray, slightly phosphatic limestone and slightly calcareous, gray shale	

Record of Well No. 3 at Iron City, Tenn. [a]

(Well drilled 100 feet east of the well (No. 1) that was drilled in 1892 or 1893. Also drilled 500 feet east of the one (No. 2) whose record is given above.)

Age and formation		Sample No.	Depth at which sample was obtained	Author's description of samples
Quaternary? Alluvium?			0–10	No sample
SILURIAN	Brassfield limestone and probably overlying Osgood limestone member of Wayne formation	1	10–15	Fine-grained, light-gray limestone with glauconite grains and red earth
	Brassfield limestone	2	15–20	Fine-grained, light-gray limestone with glauconite grains and red earth
ORDOVICIAN	Fernvale formation	3	20–25	Greenish and purple sandy shale
		4	25–34	Greenish-gray earthy, calcareous material, probably shale
		5	34–40	Rusty granular limestone
		6	40–47	Light-gray granular fossiliferous limestone
		7	47–50	
	Leipers limestone	8	51–55	Dark-gray fossiliferous granular limestone
		9	55–60	
		10	60–65	Dark-gray calcareous shale and dark-gray fossiliferous granular limestone
		11	65–70	
		12	70–75	
		13	75–78	
		14	78–83	
		15	83–88	Gray granular fossiliferous limestone
		16	88–91	Dark-gray calcareous shale and dark-gray fossiliferous granular limestone
		17	91–96	
		18	96–100	Dark-gray fossiliferous granular limestone
		19	100–105	Dark-gray calcareous shale and dark-gray fossiliferous granular limestone
		20	105–110	

[a] The cuttings from the Fernvale, Leipers, Bigby and Hermitage formations were not tested for phosphate as they were from the Seavy-Lull Well (No. 2.)

Age and formation		Sample No.	Depth at which sample was obtained	Author's description of samples
ORDOVICIAN	Bigby limestone	21	110–122	Gray fossiliferous granular limestone and some dark-gray shale
		22	122–130	Brown, fossiliferous limestone
		23	130–135	Gray fossiliferous limestone
		24	135–140	
	Bigby limestone	25	140–145	Gray fossiliferous limestone and dark-colored shale. A fossil submitted to E. O. Ulrich was determined by him to be *Zygospira recurvirostris*
		26	145–150	Dark-gray fine-grained fossiliferous limestone and some dark shale. A fossil submitted by Ulrich was determined by him to be *Zygospira recurvirostris*
		27	150–154	Dark-gray fine-grained fossiliferous limestone and some dark shale. A fossil submitted to Ulrich was determined by him to be *Dalmanella*
		28	154–159	
		29	159–161	Light-gray and dark-gray fossiliferous limestone and some dark shale
		30	161–165	Gray fossiliferous limestone
		31	165–170	
		32	170–175	
		33	175–180	
		34	180–185	Dark-gray limestone
		35	185–190	Dark-gray limestone and calcareous shale
		36	190–195	Dark-gray limestone
		37	195–200	Gray limestone; some dark shale
	Hermitage formation	38	200–205	Dark-gray fine-grained limestone and some dark shale
		39	205–210	
		40	210–213	Dark-gray fine-grained limestone
		41	215–220	Dark-gray fine-grained limestone and black shale
		42	220–225	Dark shale
		43	225–229	Dark-gray fine-grained limestone and some dark shale
		44	229–236	Dark shale
		45	236–242	
		46	242–247	Dark shale and fine-grained dark-gray limestone
		47	247–251	Dark shale and fine-grained dark-gray limestone with some white barite
		48	251–254	Dark shale and fine-grained dark-gray limestone
		49	254–259	Dark shale and fine-grained dark-gray fossiliferous limestone
		50	259–264	Dark shale
		51	264–269	Dark shale and dark-gray fine-grained limestone

Age and formation		Sample No.	Depth at which sample was obtained	Author's description of samples
ORDOVICIAN	Hermitage formation	52	269–274	Dark shale
		53	274–280	Dark sandy shale and dark-gray fine-grained limestone
		54	280–285	Dark shale and dark-gray fine-grained limestone
		55	285–290	Dark sandy shale
		56	290–295	
		57	295–299	Dark shale and dark-gray fine-grained limestone
		58	299–303	Dark sandy shale
		59	303–307	Dark shale and dark-gray sandy fine-grained limestone
		60	307–311	Dark-gray fine-grained sandy limestone
		61	311–315	Dark sandy shale
		62	315–319	
			319–323	No sample
		64	323–326	Dark sandy laminated shale
	Carters limestone	65	326–330	Compact very fine-grained dove-colored limestone
		66	330–334	
		67	334–341	Compact very fine-grained whitish gray limestone

Partial record of Well No. 4, Iron City, Tenn.

(Drilled near the Iron City Spring)

Age and formation		Depth (in feet) at which sample was obtained	Author's descriptions of samples	Remarks by E. L. Lull
SILURIAN	Wayne formation, including Osgood, Laurel, Waldon, and Lego members	3–48	Pinkish compact limestone	
		48–53	Red earthy limestone	
ORDOVICIAN	Fernvale formation	53–58	Greenish earthy sandy limestone	
		58–63	Sample not available	
		63–74	Greenish earth	
		74–78	Gray shale	
		78–83	Greenish-gray shale	
		83–88	Gray coarse-grained limestone	
		88–93	Light-gray coarse-grained limestone	
	Leipers limestone, Bigby limestone, and Hermitage formation	93–290	Samples not available	
		290–300	Dark-colored shale	
		300–314		
		314–329		
		329–365		
		365–371	Sample not available	Base of Hermitage at 371 feet

Age and formation		Depth (in feet) at which sample was obtained	Author's descriptions of samples	Remarks by E. L. Lull
ORDOVICIAN	Carters limestone	371–381	Samples not available	
		381–389	Dove-colored fine-grained limestone	
		389–393		
		393–402	Samples not available	
		402–412	Cream-colored fine-grained limestone	
		412–420	Dark-gray medium-grained limestone	
		420–424	Dark-gray medium-grained sandy limestone	Some gas; was set on fire at mouth of well
		424–428	Dark-gray medium-grained limestone	
		428–432		
		432–436		
		436–440	Brownish apparently coarse-grained limestone	
		440–444	Dark-colored fine-grained limestone	Show of oil
		444–449	Dove-colored fine-grained limestone	
		449–454		
		454–456	Sample not available	
		456–465	Dove-colored fine-grained limestone	
		466–469		
		469–473		
		473–478	Sample not available	
		479–487	Dove-colored fine-grained limestone	
		487–490		
		490–494		
		494–497		
		497–500		
		500–505	Dove-colored fine-grained limestone	Gas sand
		505–509	Dove-colored fine-grained limestone	
		509–513	Bluish fine-grained or compact limestone	
		513–517		
	Limestone older than the Carters	517–521	Sample not available	
		521–525	Bluish fine-grained limestone	Gas sand
		525–531	Bluish fine-grained limestone	
		531–545	Samples not available	Coffee-colored limestone; show of oil
		545–550	Cream-colored fine-grained limestone	
		550–553		
		553–557		

Age and formation	Depth (in feet) at which sample was obtained	Author's descriptions of samples	Remarks by E. L. Lull
ORDOVICIAN — Limestones older than the Carters	557–560	Dove-colored fine-grained limestone	
	560–564	Dark-gray fine-grained limestone	
	564–568	Whitish fine-grained limestone	
	568–572		
	572–574	No sample	
	574–578	Whitish fine-grained limestone	
	578–582		
	582–586		
	586–590		
	590–598		
	598–602		
	602–606	Dark-gray fine-grained limestone	
	606–610		
	610–614		
	614–618		
	618–622		
	622–629	Whitish and dark-gray fine-grained limestone	
	629–636	Dark-gray fine-grained limestone	
	636–640		
	640–646		
	646–649		
	650–653	Whitish fine-grained limestone	
	653–657	Fine-grained light to dark gray sandy limestone	Scum obtained on water was thought by driller to have been oil
	657–661	Light-gray fine-grained limestone	
	661–665		
	665–669		
	669–673		
	673–677		
	677–880	Samples not available	There was no material change in these samples from the lowest ones that were examined by H. D. Miser

Partial record of a well at Collinwood, Tenn.
(The depth of the well is 260 feet)

Age and formation		Depth (in feet)	Descriptions of rocks and remarks by driller
CRETACEOUS	Tuscaloosa gravel	0–4	Clay
		4–44	Chert conglomerate
		44–53½	Gravel, loose (water)
CARBONIFEROUS	Residual chert from St. Louis limestone	53½–80	Chert, red, very hard. More water at 64 feet, about 18,000 gallons per 24 hours
		80–106	Chert, very red
		106–140	Chert, harder, not so red
		140–180	Chert, very hard
	Fort Payne chert	180–185	Shale, yellow, soft
		185–210	Chert, purple, hard. Water at 210 feet, enough to drill with; about 75 gallons per hour.
		210–240	Chert, white, soft with hard streaks. Good flow of water at 240 feet.
		240–245	Limestone, shale, and chert layers
		245–260	Manganese ore. (This is probably a black flint instead of manganese ore.)

Partial record of well drilled in 1919 at Collinwood, Tenn.
(The depth of the well was 1512 feet. A complete record is not available.)

Age and formation		Depth (in feet) at which sample was obtained	Description of samples by H. D. Miser
Carboniferous	Fort Payne chert	300	Flint makes up large part of sample. Rock at this depth was apparently very hard as sample consists entirely of fine pieces
ORDOVICIAN	Carters and older limestones	1000	Compact dove-colored limestone and gray limestone with grains of medium size
		1034	Same as above except the gray limestone predominates
		1040	Compact dove-colored limestone
		1050	Compact dove-colored fossiliferous limestone*a*
		1104	Compact dove-colored limestone
		1110	Compact very light gray almost white limestone
		1116–1122	Compact dove-colored fossiliferous limestone*a*
		1123–1129	Dark dove-colored compact limestone
		1154–1160	Compact dark dove-colored limestone
		1160–1166	Compact dark dove-colored limestone

*a*Fossils from these samples were examined by E. O. Ulrich who reports as follows: The material, of course, is very fragmentary and on the whole very indecisive in its stratigraphic indications. That from 1050-foot level contains a small Rhynchonellid shell, which possibly is a *Protorhyncha*, and fragment of the cranidium of a small *Bumastus* or *Illaenus*. The second somewhat deeper level (1116-1122) contains a small, perhaps young *Rafinesquina* and a valve of an ostracod apparently belonging to the genus *Leperditella*. I hesitate in referring either one to its particular species. However, both pairs of these fossils might very well occur in rocks of the Stones River age. Similar forms occur in the Lowville, but in my judgement these belong in and preferably beneath the Carters limestone.

Generalized complete record of last named well (1,512 feet deep) at Collinwood, Tenn.

(Record is based on above-described cuttings, on the record of the well at Collinwood that is 260 feet deep, and on the thicknesses of the Ordovician and Silurian rocks at Iron City. It will doubtless be revised if careful records are kept during the drilling of other deep wells at Collinwood.)

Age and formation	Depth in feet	Thickness in feet	General character of rocks
Cretaceous:			
Tucsaloosa gravel	0–53½	53½	Gravel
Carboniferous:			
St. Louis limestone	53½–180	126½	Hard residual chert
Fort Payne chert	180–325	145	Chert, shale, and limestone
Devonian or Carboniferous:			
Chattanooga shale	325–335	10	Shale and sandstone
Silurian:			
Wayne formation	335–390	55	Limestone
Brassfield limestone	390–400	10	Limestone
Ordovician:			
Fernvale formation, Leipers limestone?, Bigby limestone?, Hermitage formation	400–706	306	Limestone and some shale
Carters limestone and older rocks: May include upper part of Knox-dolomite	706–1512	806	Includes limestone and possibly some dolomite

STRUCTURE

GENERAL FEATURES

The rocks of the Waynesboro quadrangle have been deformed but little since their deposition in a nearly horizontal position. They lie upon the extreme southwest flank of the Nashville dome. They have a gentle dip to the south and southwest. They have been bent into numerous small domes and depressions which are parts of gentle but irregular anticlinal and synclinal folds. The general structure of the quadrangle consists of a terrace in the northern part which, about the middle of the quadrangle, merges into a monocline that extends into the Warrior coal basin of Alabama. The principal local anticline crosses the center of the quadrangle, with a northeastward trend.

The rocks of the quadrangle are comparatively free from faults. Only four were observed, but another occurs just outside the quadrangle. They are all normal faults, and of small extent.

MODE OF REPRESENTATION

The structure of the rocks is represented on the accompanying map (Plate I, in pocket), which shows contour lines on the deformed upper surface of the Chattanooga shale as determined by the outcrops of that shale and overlying formations. The Chattanooga, although thin, is one of the most widely exposed formations in the quadrangle and is one of the most easily recognized. The map does not necessarily represent exactly the structure of the other formations because most of them are not present everywhere and because even where they are present their thicknesses are not uniform. The relief of the deformed surface in any portion of the quadrangle is shown by the contour lines on the map, which represent intervals of 50 feet, the numbers showing elevations above the sea.

FOLDS

Anticlines and domes

The Collinwood anticline, named from Collinwood which is near its axis, is by far the largest fold in the Waynesboro quadrangle. It extends from near Powells Mill in the southwestern part of the area, northeastward across the center of the quadrangle, terminating in the northeast corner of Wayne County and the northwest corner of Lawrence County. It is irregular in shape, and the more prominent irregularities are here mentioned. One prong near Ovilla trends eastward, another prong that is southwest of Allens Creek trends northward, and another, though lower, prong which is later described as the Wayland Springs anticline runs southeastward to the southeast corner of the quadrangle. The highest part is southwest of Allens Creek; there the elevation of the Chattanooga shale exceeds 800 feet above sea level. This part also

contains the oldest exposed rocks. These rocks belong to the Fernvale formation and are exposed along Blowing Spring Branch, a tributary of Fortyeight Creek. The dip away from the axis is in most places between 25 and 40 feet to the mile, but the northwest and southwest slopes of the anticline merge into minor anticlinal folds.

The Wayland Springs anticline which might be called a prong of Collinwood anticline is in the southeast part of the quadrangle. It trends in a southeast direction, merging to the northwest with the Collinwood anticline and terminating to the southeast near St. Joseph. Its highest part is a low nearly circular domelike area on Shoal Creek and the lower course of Factory Creek just northeast of Wayland Springs. This part is steepest on the northeast side where the dip is 100 feet in half a mile. The oldest rocks revealed by erosion on its crest belong to the Leipers limestone. Another but smaller dome occupies the crest of the anticline 3 miles south of west of West Point. The oldest rocks exposed on it belong to the Wayne formation. Three wells drilled at Iron City on the southwest slope of the anticline obtained a small flow of gas from the Bigby and Hermitage formations. Descriptions of these wells are given on pages 147 and 148.

The Waynesboro anticline is L-shaped and culminates in two small domes, one of which is about a mile north of Waynesboro and the other about 1½ miles west of that place. Both domes are about the same height. Erosion has, however, cut deeper into the one than the other. The Osgood earthy limestone and higher members of the Wayne formation are the oldest exposed rocks on the crest of the dome north of Waynesboro, and the Chattanooga shale is the oldest exposed formation on the crest of the one west of that place.

A small dome, attaining an elevation of over 650 feet above sea level, is on the divide between Hardin and Flat Gap creeks, on the west side of the quadrangle. The oldest strata exposed on its crest belong to the Dixon earthy limestone member of the Wayne formation.

The Eagle Creek anticlines are south-southeast of Clifton and are between that town and Eagle Creek. Both are small but the one to the south is the higher. It trends in a northeast direction parallel with the course of Eagle Creek, which flows in a narrow syncline along the southeast side of the anticline. The other anticline trends westward and is separated from the one to the south by a syncline. The oldest formation exposed on the crest of the higher anticline is the Hermitage while the oldest on the crest of the lower one is the Fernvale.

The crest of a dome or anticline, as indicated by excellent rock exposures along the right bank of Tennessee River, is located at the old cement furnace at the west edge of Clifton. This furnace is just west of the area shown on the accompanying map (in pocket). A normal fault, which is described on page 41, runs in a nearly northward direction across the crest a short distance west of the cement plant.

Three anticlinal folds are near Beech Creek in the northwest part of the quadrangle. One of these is on the west edge of the quadrangle north of the mouth of Beech Creek; it trends almost east and west. The second is just north of Little Beech Creek. It trends in a northeastward direction; is triangular in outline and reveals the Hermitage formation on its crest, which is occupied by the valley of a small tributary of Little Beech Creek. The third, of irregular shape, is on the divide between Beech Creek and Buffalo River, 4 miles west of south of Flatwoods. The highest part, which is at the east end, has been cut into by a small tributary of Beech Creek. The Hermitage is the oldest exposed formation on this tributary.

A number of other anticlines which are lower than the ones described above occur in the northern and western parts of the quadrangle. Among them are one just north of Martins Mill, one 3 miles north-northwest of Houston, one 2½ miles northeast of Clifton, one 6 miles nearly due east of Clifton, and one 3 miles east-northeast of Riverside. These are all shown on the accompanying map (Plate I, in pocket).

Basins

Several basin-like or synclinal folds in the upper surface of the Chattanooga shale occur in different parts of the quadrangle, but most of them are along the larger streams. They are discussed under the heading, "Relation of Structure to Drainage" on page 41.

FAULTS

A small fault apparently less than half a mile in length is on Little Beech Creek 7 miles northeast of Clifton and three-fourths of a mile above the mouth of Bost Fork. The rock exposures are not sufficiently numerous to determine accurately the direction of the trend of the fault or the amount of the downthrow, but the trend is apparently to the southeast. The rocks on either side of the fault dip gently to the southwest, and the Lego limestone or Laurel limestone has been displaced so that it is in contact with the Fernvale formation at the level of the creek. The downthrow is on the southwest side and is apparently about 50 feet.

A fault with an apparent trend of east by north and a length of half a mile or more is 2¼ miles south-southeast of Peters Landing on Tennessee River. It is in a small syncline and its trend is parallel with the trend of the axis of the syncline. The downthrow is on the south side and is apparently between 50 and 100 feet; the rock exposures in this vicinity are not sufficient to determine accurately the amount of downthrow.

A small fault is revealed in a large outcrop of the Fernvale formation on the southeast point of the hill just west of Rhodes Hill station. It is the northeast side of the crest of a part of the Wayland Springs

anticline. The fault has a trend of S. 50° E. and the downthrow, as shown by the different elevations of the top of the limestone in the lower part of the Fernvale on either side of the fault, is 7 feet and is on the northeast side.

A north-south fault with a downthrow of 9 feet on the east side is revealed on the right bank of Fortyeight Creek 1 mile south of Fortyeight post office. The rocks that are cut by the fault include the Wayne formation, the Hardin sandstone, and probably the Fort Payne chert.

A fifth fault which was observed is near Clifton just west of the Waynesboro quadrangle. It is a short distance west of the old cement plant at that place and apparently trends in a nearly northward direction across the crest of a dome or anticline. The downthrow is about 75 feet and is on the west side. The oldest rock formation exposed on the east side of the fault is the Hermitage and the oldest on the west side is the Brassfield limestone.

RELATION OF STRUCTURE TO DRAINAGE

A striking relation between the drainage and the folds in the rocks is apparent from the accompanying map, but would probably be more so from a structure map with a much smaller contour interval than 50 feet. The drainage, which is radial from the central part of the quadrangle, is away from the axis of the Collinwood anticline, the principal anticline which, as above indicated, extends from near Powells Mill in a northeastward direction to the vicinity of Allens Creek and Strathmore. The divide between the drainings on the two sides of the anticline therefore coincides very closely with the axis of the anticline.

Many of the larger streams, including Factory, Indian, Hardin, Eagle, Beech, and Fortyeight creeks and Green and Buffalo rivers, flow partly or wholly in synclinal folds that occur on either side of the Collinwood anticline. On the other hand, Shoal Creek takes an unexpected course across a comparatively large dome, and Chisholm and Holly creeks do not bear any relation to the minor anticlinal or synclinal folds. As many of the larger streams occupy synclinal folds, most of their tributaries flow toward the axes of the synclines and thus with the dip of the rocks. The grade of the streams in many places is the same or nearly the same as the downstream dip of the rocks.

From the above it is obvious that the structure has in great measure controlled the courses of the streams.

MINERAL RESOURCES

The mineral resources of the Waynesboro quadrangle that have been utilized include limestone for flux, limestone for lime, limestone for building stone, road material, flint for lining tube mills, millstones, manganese ore, cement rock, clays, gravel, sand, and brown iron ores. Of these the brown iron ores are the most important. These resources, together with the water resources, soils, forests and undeveloped mineral resources, are described on the pages that follow.

BROWN IRON-ORE DEPOSITS

GENERAL FEATURES

The brown iron-ore deposits of the Waynesboro quadrangle occur in "The Western Iron-Region[1]" of Tennessee. This region is a part of a broad iron-ore belt which extends from the Russellville district in northwestern Alabama across Tennessee into western Kentucky. The deposits are mostly east of Tennessee River but those of the Russellville district are south of the river and some in Tennessee are west of it.

The workable deposits of iron ore in the Waynesboro quadrangle may be grouped into three types, according to the rocks with which they are associated:

1. Deposits associated with the St. Louis limestone, of Mississippian age, and the Tuscaloosa gravel, of Upper Cretaceous age. These deposits occur in the residual chert and clay of the St. Louis limestone and in pockets or lenses of the Tuscaloosa gravel that are found in and above the chert and clay. They are on or near the crests of the ridges in the east half of the quadrangle.

2. Deposits associated with rocks of Devonian age. These deposits are residual from rocks of this age and occur in the northwest part of the quadrangle.

3. Deposits in the Brassfield limestone, of Silurian age. These deposits so far as known occur only near Iron City.

All of these types have been worked. The deposits that are associated with the St. Louis limestone and Tuscaloosa gravel have, however, produced the bulk of the marketed ores from the quadrangle and contain much larger available reserves of iron ore than the other types.

The features of these different types and the mines and prospects of each type are for the most part described separately. The deposits associated with the St. Louis limestone and Tuscaloosa gravel are described on pages 43 to 116; the deposits associated with rocks of Devonian age are described on pages 116 to 118; and the deposits in the Brassfield limestone are described on pages 118 and 119.

[1]Safford, J. M., Geology of Tennessee, pp. 449, 460-463, 1869.

A

B

(A) Pinnacle of sand in the Pinkney mine, just west of Pinkney.
(B) Ruins of Van Leer Furnace on Butler Creek, 2¼ miles west-southwest of Iron City. Operated from 1832 to 1837.

DEPOSITS ASSOCIATED WITH THE ST. LOUIS LIMESTONE AND TUSCALOOSA GRAVEL

LOCATION

The deposits that are associated with the St. Louis limestone and Tuscaloosa gravel are confined almost entirely to the east half of the Waynesboro quadrangle. The distribution of deposits that were examined by the writer and many that were examined by Reese F. Rogers[1] is shown on the accompanying map (Plate I, in pocket). Most of the deposits that were examined by Rogers were not examined by the present writer.

The deposits are irregularly distributed in a belt 12 miles wide which extends entirely across the quadrangle along its east border, and which comprises the southern part of Lewis County, the western part of Lawrence County, and the eastern part of Wayne County. Only three known deposits are outside this belt; these are on Cypress Creek near Cypress Inn in Wayne County (see Plate I, in pocket).

Many of the deposits and most of the iron-ore mines are near McLean, Nancy, Riverside, and Allens Creek on the Centerville Branch of the Nashville, Chattanooga and St. Louis Railway; near Pinkney, West Point, Rhodes Hill, and Wayland Springs on the Pinkney Branch of the Louisville and Nashville Railroad; near Iron City on the Columbia, Florence and Sheffield Branch of the Louisville and Nashville Railroad; and near Geneva, Corning, and Hardwick, on the Tennessee Western Railroad. Many deposits including those at and near Wayne Furnace and those near Moon and Lodi are 5 to 8 miles in a straight line from the nearest railroads and the deposits near Cypress Inn are from 10 to 13 miles in a straight line south-southwest of Collinwood. The construction of a railroad, 16 miles long, from Collinwood to Wayne Furnace was begun in 1920, and 10 miles of the road bed had been graded and 3 miles of the steel rails had been laid before April, 1921.

HISTORY OF IRON INDUSTRY

Iron Ore has been mined in the Waynesboro quadrangle for many years, the first mining having been done about 1832. Depending on the methods used in mining and treating the ores the history may be divided into two periods, the first beginning about 1832 and ending in 1875 and the second beginning about 1887 and continuing to the present.

During the first period the ore was mined by hand and was hand cobbled to free it so far as possible from the chert and clay that were associated with it. Much of it was dry screened to separate the larger particles of ore from the clay and fine ore and small rock fragments; and

[1]Rogers, Reese F., The iron ore deposits of Lewis County, Tennessee: The Resources of Tennessee, Vol. 5, No. 3, pp. 91-146, July, 1915.

some of the crude ore was placed on ricks of wood which were then burned, the object being to obtain an ore more nearly free from chert and clay. The methods of mining and treating the ores at that time are more fully described (pages 79 to 109), under the headings "Wayne Furnace Mines" (pages 79 to 90), and "Van Leer Mine" (page 109). The ore was smelted into pig iron in charcoal furnaces or in forges which were erected near the mines. Furthermore, the mining and smelting industries were carried on in this region without the aid of railroad transportation.

Three furnaces and one forge were operated in the Waynesboro quadrangle in the period from 1832 to 1875. These were Van Leer Furnace on Butler Creek 2¼ miles west-southwest of Iron City; Wayne Furnace on Furnace Branch 5 miles east by north of Waynesboro; Marion Furnace 2 miles south of Clifton; and Fortyeight Forge on Fortyeight Creek 1 mile south of the bridge on the Waynesboro-Lawrenceburg Road. The operation of these and of the mines that supplied iron ore for them is briefly described below.

Van Leer Furnace (see Plate III, B) and the mine from which iron ore was obtained for it were operated by Sam Van Leer from 1832 to 1837. The furnace was run by water power. The pig iron was shipped down Tennessee River to the Ohio, thence on the Mississippi to New Orleans and from there to Baltimore. The mine that supplied it with ore is on the crest of the ridge between Holly and Butler Creeks 1½ miles northwest of Iron City, and the production of iron ore at that early date, as estimated by Dr. L. J. Gray of Iron City, was 40,000 tons. The ore-bearing tract on which the old mine is located has changed ownership and has been subdivided so that it now occurs on four different though adjoining properties. The mines on each of these properties are herein described as the Van Leer, Seavy-Lull, Bromly, and Pruitt mines. The bulk of the 40,000 tons was obtained from the Van Leer mine. The mining by Mr. Van Leer was done by slave labor. Only the large lumps that could be sorted from the clay were used; no attempt was made to wash out the "shot ore." This hand-sorted lump ore was placed on ricks of wood and then the wood was burned so as to free the ore from the clay as completely as possible. Then the ore was loaded on wagons by means of forks and hauled to the furnace 1½ miles southwest of the mine. Mining was not resumed at this locality until 1919 when it was begun by J. J. Gray, Jr., on the Van Leer and Seavy-Lull mines. In 1916, 4 or 5 tons of pig iron was taken from the hearth of the Van Leer Furnace and was hauled to Iron City where it was sold as scrap iron. The source of the limestone for use as flux in the furnace is not known. No limestone is exposed on Butler Creek near the furnace.

Fortyeight Forge was one of the earliest forges to be operated in this part of Tennessee. The exact date of its operation is not known, though it is said to have been before the erection of Wayne Furnace which took place in 1833. The locality from which the iron ore was

obtained is not known but it was probably obtained from property that is now owned by the Tennessee Charcoal Iron Co. Old near-by openings on this property which supplied ore for Wayne Furnace and probably also for the forge on Fortyeight Creek are at the Murphy, Crews, Sapling, West, and Lee Hollow mines. The stack was located on a steep hillslope on the east side of the creek near the forge. The creek was dammed at the forge to provide the water power for the operation of the forge and the stack. The old ruins at this locality and pieces of scrap iron may still be seen.

Wayne Furnace was built by the Fargisons in 1833 and was operated by them and other parties much of the time from that date until 1875. It was closed in 1875 and has not been operated since then. Iron ore for the furnace was obtained from several mines within a radius of 2 miles and the quantity of ore thus used is estimated to have been 145,000 tons. The mines have not been worked since 1875 though some prospecting has been done. The operation of the furnace and the mines is fully described on pages 79 and 82.

Wayne, Cumberland and Brownsport furnaces are said to have been the largest charcoal iron furnaces in Tennessee from 1868 to 1876, but the production of pig iron from Wayne Furnace during this time exceeded that of the others. Cumberland Furnace was in Dickson County north-northeast of the Waynesboro quadrangle and Brownsport Furnace was in Decatur County 10 miles north-northwest of Clifton.

Marion Furnace, also known as the Walker Furnace, was operated before the Civil War and is said to have furnished iron for cannon balls for the Mexican War. It was located near the Hughes Hollow Spring, 2 miles south of Clifton, and on land that is owned by T. S. Hassell of Clifton. The iron ore for it was obtained at the Sanders mine which is 1½ miles south-southeast of Clifton. The ore at this mine is largely the hematite variety of brown iron ore and is residual from a limestone of Devonian age. It is described on pages 116 and 117. Charcoal instead of coke was used in the furnace, and a sufficient supply of limestone suitable for flux was found in the Decatur limestone which crops out on the hillslope east of the spring.

Another furnace which was located at Furnace Landing on the south side of Tennessee River 1 mile west of Clifton was operated at the same time as the Marion Furnace. This was, however, just west of the area described in this report.

During the second period of the industry from 1887 to the present, modern methods of mining and treating the ores have been used and railroad transportation has been available, in consequence of which the quantity of mined ore is many times that of the earlier period. Practically all of the ore has been mined by steam shovels and has been hauled on tram roads from the mines to near-by washing plants where it was concentrated, and then the marketed ore has been conveyed over rail-

roads to the furnaces, most of which are outside the Waynesboro quadrangle. For the location of the blast furnaces in west-central Tennessee and the adjoining part of Alabama, see Fig. 1. The present methods of mining and treating the ores are described on pages 62 and 63. The following paragraphs give the principal events in the iron-ore mining industry in the quadrangle from 1887 to the present.

The Allens Creek mines were opened in 1891 and have been operated much of the time since then, the operators being the Southern Iron Co., the Buffalo Iron Co., the Bon Air Coal & Iron Co., and the Bon Air Coal & Iron Corporation, the last of which is the present operator. Two furnaces known as Mannie Furnace No. 1 and Mannie Furnace No. 2 were erected in 1892 to smelt ore from the mine and they have been operated whenever the mines have been operated (see Plate IV, A). Charcoal was used in the furnaces from 1892 until 1900 when the use of coke was begun.

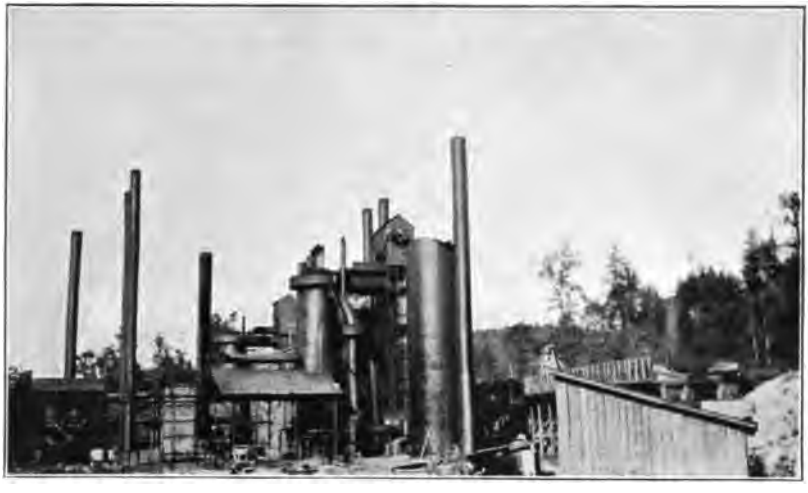
The Warner Iron Co. opened the Percy mine in 1899 and continued to operate it much of the time until January 27, 1919, when the mine was purchased by the Bon Air Coal & Iron Corporation. The latter company was operating the mine at the time of the writer's last visit (April, 1920). The Warner Iron Co. shipped all of its output of the washed ore to the Cumberland Furnace, Cumberland Furnace Post Office, Dickson County, Tennessee, and the Bon Air Coal & Iron Corporation has shipped its production of washed ore to this and also to the Goodrich Furnace, Goodrich, Hickman County, Tennessee.

The Sharp mine was worked by the Smith and Sharp Mining & Manufacturing Company and the West Point Mining & Manufacturing Company for several years beginning in 1888. Smith and Sharp also operated the Powell mine many years ago. They mined the ore at the Powell mine with pick and shovel and then hauled it on tram cars to the washing plant. The West Point Mining & Manufacturing Company worked the Ironsides mine for a few years before 1904.

J. Craig McClanahan operated the Pinkney mine from 1887 to 1900 and shipped the washed ore to Sheffield, Alabama. He operated the Wright mine from 1897 to 1900 and shipped the washed ore to Sheffield, Alabama, and South Pittsburg, Tennessee.

The Pinkney mine was later operated from 1902 to 1912, by Daniel King for the Pinkney Mining Company, and the Little Hill mine was also operated by Mr. King for this company for a few years beginning in 1902. The washed ore was shipped to Cumberland Furnace; Helen Furnace, Clarksville, Montgomery County, Tennessee; and to furnaces at Sheffield, Alabama.

J. J. Gray, Jr., operated the Little Hill mine from 1906 to 1911 and the Dodd mine from 1907 to 1913 or 1914 and shipped the washed ore to his furnace (Rockdale Furnace), at Rockdale, Maury County, Tennessee, for use with phosphate rock in the manufacture of ferrophosphorus.



(A) Mannie Furnace of Bon Air Coal and Iron Corporation at Allen's Creek.

(B) One of the main cuts at the Percy mine, 1 mile southwest of Riverside.

In 1919 he began the operation of the Van Leer and Seavy-Lull mines and they were being operated at the time of visit (April, 1920). Some of the washed ore from these mines was being shipped to Sheffield, Alabama, where it was used in making pig iron; the rest was being shipped to Rockdale, Tennessee, for the manufacture of ferrophosphorus.

The Sheffield Coal & Iron Company mined ore at the Ironsides mine for a few years ending in 1904. It also worked the Hessemer No. 1 and No. 2 mines from 1902 to 1907 and shipped the washed ore to Sheffield, Alabama, and it worked the Couch mine from 1909 to 1912 and the Gresham mine from 1913 to 1915.

The Napier Iron Works mined ore at the Burkett, Wisdom and Drake mines from 1905 to 1912, at the Elting and J. B. Powell mines in 1917 and 1918, at a mine on the property of the Tennessee Charcoal Iron Company in 1918, and at the Robinson (White-Littrell) mine in 1918, 1919, and 1920. The washed ore from all of these mines was shipped to Napier Furnace, Napier, Lewis County, Tennessee.

The Ohio Mining Company erected a washing plant at the Hardwick mine in 1917 and 1918 and operated the mine and plant for a short time in the latter part of the year.

The Tennessee Valley Iron & Railroad Company worked the Hardwick mine for a short time early in 1920 and resumed the operation of the mine in the latter part of 1920 after the company had been reorganized and had become the Tennessee Charcoal Iron Company. The washed ore from the mine was shipped to Anna Furnace at Collinwood. This furnace is a charcoal iron furnace and was erected at Collinwood during the World War by the Tennessee Valley Iron & Railroad Company. Its operation was begun in August, 1920, by the Tennessee Charcoal Iron Company and was continued until December, 1920, when it was stopped temporarily. The last named company has begun the construction of 16 miles of railroad running from Collinwood to Wayne Furnace. It has also planned to mine iron ore from some of the iron-ore deposits at Wayne Furnace.

Prospecting has been done from time to time at some of the old abandoned mines and has also been done at numerous localities where there has been no mining.

PRODUCTION OF IRON ORE

The production of iron ore in the Waynesboro quadrangle from 1832 to 1920, inclusive, aggregates about 5,405,000 tons. The production by mines is given in the accompanying table. The figures of production in the table were in part taken from articles by A. H. Purdue[1] and E. L. Lull[2]

[1]Purdue, A. H., The iron industry of Lawrence and Wayne counties: The Resources of Tennessee, vol. 2, No. 10, pp. 370-388, Oct., 1912.

[2]Lull, E. L., An important southern ore field: The Iron Age, vol. 90, No. 25, p. 1423, Dec 19, 1912.

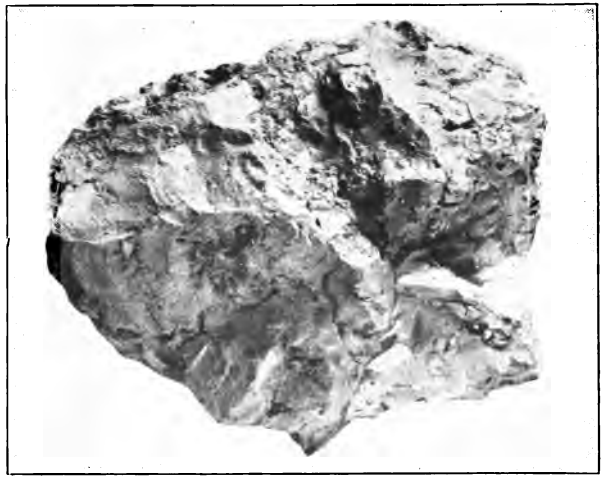
but most of them were obtained by the writer from the different mine operators.

Production of iron ore in the Waynesboro quadrangle, Tennessee, 1832 to 1920 inclusive

	Tons
Allens Creek mines (28)*a*	1,255,693
Percy mine (29)	469,481
Wayne Furnace mines: East Furnace Ridge mine (32), West Furnace Ridge mine (33), Nigger Ridge mine (34), Lee Ridge mine (36), Broach mine (37), Keaton Springs mine (38), Perigo mine (39), Irontop mine (40), Murphy mine (41), Crews mine (42), Sapling mine (43), West mine (44), Lee Hollow mines (45)	145,000
Wright mine (53)	506,000
Pinkney mine (54)	962,500
Ironsides mine (55)	650,000
Sharp mine (56), Burkett mine (57), Wisdom mine (58), Drake mine (59)	400,000
Hessemer No. 1 mine (61)	170,000
Hessemer No. 2 mine (60)	130,000
Little Hill mine (62), Dodd mine (63)	150,000
Couch mine (65)	196,000
Gresham mine (66)	65,138
Elting mine (69)	25,651
J. B. Powell mine (70)	28,618
Mine of Tennessee Charcoal Iron Co. (71)	7,000
Robinson (White-Littrell) mine (72)	134,610
Hardwick mine (73)	150*b*
Van Leer mine (83), Seavy-Lull mine (84), Bromley mine (85), Pruitt mine (86)	40,000*c*
Van Leer mine (83)	8,445*d*
Seavy-Lull mine (84)	714*e*
Powell mine (87)	50,000*f*
Cedar Point mine (89)	10,000
Sanders mine (92)	(*g*)
Total	5,405,000

*a*Numbers refer to location on map (in pocket).
*b*Production before April, 1920.
*c*Production, 1832-1837.
*d*Production, from Dec., 1919, to March, 1920, inclusive.
*e*Production in 1919 and 1920 prior to April, 1920.
*f*Production not known, but estimated by writer.
*g*Production not known.

(A) Specimen of brown iron ore with a botryoidal surface. From the East Furnace Ridge mine at Wayne Furnace. Two-thirds natural size.



(B) Massive compact brown iron ore. Two-thirds natural size.

MINERAL COMPOSITION OF THE ORES

The ore is generally termed limonite but is also known as brown hematite and in the trade is commonly known as brown iron ore. It is composed entirely of iron oxides of which two or more of the following are present: hematite, turgite, goethite, limonite and xanthosiderite. These minerals are closely related, all agreeing in containing their iron in the ferric form, as the sesquioxide (Fe_2O_3) and are therefore regarded as belonging to the hematite or sesquioxide group of iron oxides. The species of the group differ in the amounts of chemically combined water. Hematite proper, usually distinguished as red or specular hematite, contains no combined water. The other members of the group contain more or less water and differ in the amount of water which is chemically combined with their iron oxide.

The relation between these various iron-oxide minerals is best brought out if their formulas be so arranged as to give a constant iron factor. This arrangement of the formulas and the percentage of iron in each mineral is given in the table below:

Chemical character of different iron-oxide minerals

Name of mineral	Chemical formula	Composition		
		Iron oxide	Iron	Water
		Per cent	Per cent	Per cent
Hematite	$2Fe_2O_3 . OH_2O$	100.	70.	0.
Turgite	$2Fe_2O_3 . 1H_2O$	94.7	66.2	5.3
Goethite	$2Fe_2O_3 . 2H_2O$	89.9	62.9	10.1
Limonite	$2Fe_2O_3 . 3H_2O$	85.5	59.8	14.5
Xanthosiderite	$2Fe_2O_3 . 4H_2O$	81.6	57.0	18.4

From this table it will be seen that the five minerals in question make up a perfect series with respect to their percentages of combined water, beginning with hematite which contains no water and showing gradually increased amounts to the other end of the series. The table also shows a decrease in the percentage of iron from hematite toward the other end of the series. The percentage of iron as given in the table are theoretical and will never be found in the ores in the Waynesboro quadrangle because all of the ores contain more or less impurities.

The four hydrous oxides, turgite, goethite, limonite, and xanthosiderite, are commonly grouped under the names of brown-iron ores, or limonite. It is probable that if the product from any particular brown-ore deposit in the Waynesboro quadrangle be carefully examined, it will be found that much of the ore is limonite proper, with much goethite, and smaller proportions of the other two hydrous oxides. Hematite, if present in the quadrangle, occurs in very small quantity. In the present report the iron oxide minerals are called simply brown iron oxides or red oxides according to their color.

Limonite is not crystallized; most of it is massive though some of it has botryoidal surfaces and has a fibrous structure. (See Plate V).

It has a brown or nearly black varnish-like surface and the color of freshly fractured surfaces ranges from light to dark brown. The streak is yellowish brown.

Goethite resembles limonite and has a brownish yellow to ocher-yellow streak, whereas both hematite and turgite which often resemble limonite have red streaks. Xanthosiderite occurs as fine needles or fibres and as ocher and is golden yellowish or brown to brownish black in color.

ROCKS ASSOCIATED WITH THE ORES

The iron-ore deposits occur in chert, clay, sand, and gravel. These materials form a loose mantle overlying the solid rock on the crests and slopes of every ridge in the iron-ore-bearing area on the east side of the quadrangle. This mantle is known to be 60 feet thick at places and is probably as much as 100 feet thick over much of the area. The proportion of these materials differs at different localities and also differs with depth, and one or more of them are absent at some localities. They are more or less jumbled and constitute a rather irregular mixture.

The chert and clay are residual from the St. Louis limestone, of Mississippian age. The sand and gravel are so intimately mixed with them as to suggest that they are also residual from this limestone. At some places they actually appear to be interstratified with the chert and clay. (See figure 3.) They are, however, of post-St. Louis age, as is shown by the fact that water-worn pebbles from the St Louis are an important constituent of the gravel and sand deposits. They are probably of the same age as the Tuscaloosa gravel (Upper Cretaceous) at most places; but they are probably of Tertiary or later age at some places.

An explanation for the peculiar relations of these materials at most places is here offered. The sand and gravel were laid down by streams in limestone sinks and in other surface irregularities, and possibly in

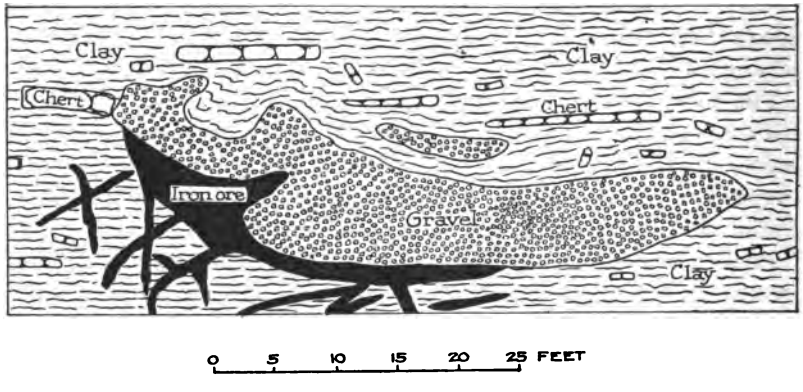


FIGURE 3.—Sketch of side of a cut at the Allens Creek mines, illustrating the occurrence of pockets of gravel in the residual cherty clay of the St. Louis limestone and also illustrating an occurrence of the iron ore.

(A) Looking west in the Couch mine, 1 mile west of Rhodes Hill. A pinnacle of unmined sandy ore is in the left foreground. Discarded boulders of siliceous ore occur on floor of cut.

(B) Side of a cut at the Hessemer No. 2 mine, ¼ mile southwest of Pinkney, showing the occurrence of small masses of ore near the surface and large masses at a greater depth.

underground channels during Upper Cretaceous time. Some residual clay and chert fragments of the St. Louis limestone were doubtless available at that time and were transported and laid down by streams with the sand and gravel. Since then the limestone, containing these sinks, irregularities, and underground channels, has been deeply weathered and has lost its calcium carbonate through solution. The less soluble constituents of the limestone which are chert and clay have been left as residual material. This material gradually became thicker and thicker during the weathering of the limestone and is now as much as 100 feet thick over a large part of the quadrangle. Very few exposures of the unweathered limestone are found in the quadrangle and none are found in the iron mines. Caving and settling of the residual material have taken place during the weathering of the limestone. Just how much has taken place can not be determined. It may have been 100 feet, 200 feet or more. In the Batesville district, Arkansas,[1] chert layers are known to have settled at least 250 feet as a result of the weathering of underlying beds of limestone. While the residual material was settling the deposits including sand and gravel, that had been laid down in limestone sinks, and in other surface irregularities and possibly in underground channels, also settled downward and have been further intermixed with clay and chert. Also as a result of this settling the chert layers have been bent and broken and their fragments have been irregularly distributed through the clay.

The intermixing of the sand and gravel with the chert and clay was probably in part accomplished by streams during the deep weathering of the St. Louis limestone and during the formation of thick deposits of clay in the Tertiary and Quaternary periods.

The clay that is in the deposits on most of the ridge crests is usually overlain by 1 to 2 feet of soil and subsoil which have been leached to a light-yellowish or a gray color. A bright red clay which ranges in thickness from a few feet to 50 feet or more occurs beneath the subsoil; and below the red clay the clays are usually yellow, but at a few places are white. Pebbles, fragments, and boulders of chert are more numerous in the yellow clay than in the red clay, soil, and subsoil. They are also in general more abundant in the lower part of the red clay than in the upper part. This is due to the breaking up of the chert by the weathering agents such as water, plants, and temperature changes. These agents work more effectively near the surface than deep beneath it; and by them much of the chert has been reduced to very fine-grained silica that is more or less evenly distributed through the clay near the surface. The clay is present in comparatively small quantities at many places, such as the Wayne Furnace mines; and in such places pebbles, fragments,

[1]Miser, H. D., Preliminary report on the deposits of manganese ore in the Batesville district, Arkansas: U. S. Geol. Survey, Bull. 715-G, pp. 116-117, Nov. 15, 1920.

and boulders of chert constitute a very large part of the ore-bearing materials and extend to the surface.

The chert occurs as angular fragments and as layers that have been much fractured. It is gray or white and much of it is hard; the rest is soft and when struck with a hammer becomes a fine powder resembling tripoli.

The sand occurs in or above the clay as irregular pockets or lenses as much as 35 feet or more thick (vertically) and as much as 100 feet long in their longest dimension. Such pockets, where they are small, are near the surface but the larger ones extend downward to a depth of 35 feet or more. They are fairly numerous in some iron ore mines but are absent or practically absent in others. Much iron ore occurs in them but all of it is very sandy and is therefore not mined. When they are encountered in mining the steam shovel passes around them so that they are left as pinnacles that rise as much as 35 feet or more above the floors of the open cuts. (See Plates III, A and VI, A). The sand in these pockets is yellow to red in color, is cross bedded, and contains many flakes of mica, thin horizontal layers of white plastic clay and a few well-rounded pebbles of chert and quartz.

The gravel also occurs in pockets or lenses in or above the clay. These pockets have much the same size as the pockets of sand. The pebbles in them are hard, and subangular to well-rounded and are usually ½ to 2 inches in diameter, though some are as much as 5 inches in diameter. They are mostly chert but are partly quartz. A few fragments of chert in the gravel pockets are angular and appear as if they had not been waterworn at all. The chert pebbles, as is indicated by fossils in them, were derived from the St. Louis limestone. The source of the quartz pebbles is not known.

MINERALS ASSOCIATED WITH THE ORES

The most abundant minerals that are associated with the iron ores are various forms of silica and clay. The silica occurs as (1) quartz sand grains disseminated through some of the ore, as pockets of loose sand in the ore and as lenses of loose sand through which the ores are irregularly distributed; (2) fragments of soft and hard chert, many of which are cemented together forming a ferruginous chert breccia; (3) minute particles of chert down to microscopic size which are disseminated through much of the ore; (4) subangular to well-rounded chert pebbles, many of which are cemented together by iron ore forming a very hard conglomerate; (5) well-rounded pebbles of milky quartz, though such pebbles are not numerous.

The clay is residual from the St. Louis limestone and contains more or less chert which is also residual from this limestone. It contains gravel and sand at many places and also contains veins and masses of iron ore of many sizes and shapes. Much of the clay adheres to the rough

(A) A fossil Bryozoan in iron ore from the Van Leer mine, 1½ miles west-northwest of Iron City. Limonite has probably replaced fossiliferous residual chert from the St. Louis limestone. Natural size.

(B) Specimen of iron ore with a polished surface from the Lee Hollow mines, 2 miles east of Wayne Furnace. Illustrates the replacement of chert (light-gray) by limonite (dark-gray). Fossil Bryozoans which were once in the chert are preserved in the ore that has replaced the chert. Four-fifths natural size.

surfaces of the masses of iron ore as they come from the mines and some of it partly fills cavities in the ore. It is white, yellow, and red in color and when wet is plastic and sticky.

Wad, a soft brownish-black impure oxide of manganese, is present in small quantities at some places in the iron ore-bearing clays.

Occurrences of cobalt minerals have been reported from time to time in the Waynesboro quadrangle and they have been investigated by private parties but thus far none of commercial importance have been discovered. The writer did not observe any cobalt minerals during the field investigation for this report, but was told of a few localities where they are said to occur associated with the iron ores.

Three iron phosphate minerals, strengite, beraunite, and cacoxenite, have been found associated with the brown ore at the Van Leer mine. They were brought to the writer's attention by Dr. L. J. Gray, superintendent of the mine, and were determined by W. T. Schaller of the U. S. Geological Survey. They occur in boulders of chert breccia whose fragments are cemented together with brown iron oxide. The strengite is white to pink in color, has a radiate structure and lines cavities. Its composition is represented by the formula $FePO_4+2H_2O$. This locality is one of the four occurrences of strengite in the United States that are known to the writer. The other occurrences are at an iron mine in Rockbridge County, Va.,[1] at a manganese prospect in Polk County, Ark.,[2] and in pegmatite dikes in San Diego County, Calif.[3] Beraunite is a reddish-brown crystalline mineral with the formula $2\,FePO_4.Fe(OH)_3+2\frac{1}{2}\,H_2O$ and cacoxenite is a canary-colored fibrous mineral with the formula $FePO_4.Fe(OH)_3+4\frac{1}{2}\,H_2O$.

The relation of the iron ore to the chert indicates that at least much of the ore replaced the chert while it was being deposited. The evidence for this follows: 1. Fossils may be seen in the ore that are like those in the chert which is associated with the ore. (See Plate VII). 2. Chert fragments that are included in the ore have irregular outlines. (See Plate VIII). 3. Fine particles of chert down to miscroscopic size are disseminated through iron ore at some distance from fragments of chert that have irregular outlines. 4. Loose, disconnected masses of bomb-shell ore, which consists of hollow masses with shells of iron oxides as much as 1 inch thick, have angular shapes like the chert fragments that are associated with the ore; and, although they are hollow, they contain some soft chert whose distribution indicates that chert once entirely filled the cavities and that it has been mostly removed through solution (see Plate IX). The shapes of these masses and the presence of the chert in them strongly suggest that the iron oxides have replaced the outer surficial zone of angular chert fragments.

[1] Dana's System of mineralogy.
[2] Discovered by writer.
[3] Reported by W. T. Schaller.

CHEMICAL COMPOSITION OF THE ORES

The iron content of the washed brown iron ore that has been marketed from the Waynesboro quadrangle has ranged from 45 to 52.5 per cent of iron and has averaged about 47 per cent. The silica and alumina have ranged from 10 to 20 and have averaged about 15 per cent. The high percentage of these constituents is due to the presence of clay and chert which could not be removed during the treatment of the ores. The amount of silica exceeds that of alumina which probably averages 3 per cent in most of the marketed ore. Manganese is apparently present in all of the ore and averages between .25 and .50 per cent. The phosphorus content is high, averaging about .75 per cent, but the sulphur content is low, averaging less than .05 per cent.

Analyses of iron ore that has been marketed from the Waynesboro quadrangle and many analyses of samples are given in the two accompanying tables.

Analyses of washed brown iron ore, Waynesboro quadrangle, Tennessee

Description of sample	Authority[a]	Iron (Fe)	Manganese (Mn)	Phosphorus (P)	Silica (SiO_2)	Alumina (Al_2O_3)
Allens Creek mine, average ..	B	47.	.25–.30	.8–1.25	15.–18.	2.5–3.5
Pinkney mine, average	K	47.	...	.70	17.50	
Ironsides mine, average.....	S	52.50	...	.83	10.10	
Couch mine, average.....	S	48.87	...	...	.....	
Elting mine, average.....	N	45–48	...	...	.....	
J. B. Powell mine, average...	N	45–48	...	...	.....	
Robinson (White-Littrell) mine, average.....	N	45–48	...	...	.....	

[a]Authorities: B, Bon Air Coal & Iron Corporation; K, Daniel King; S, Sheffield Coal & Iron Co.; N, Napier Iron Works.

Analyses of samples of brown iron ores, Waynesboro quadrangle, Tennessee

Locality	Analyst	Iron (Fe)	Manganese (Mn)	Phosphorus (P)	(Sulphur) (S)	Silica (SiO_2)
Morton property[a]	Paul C. Bowers...	56.36	....	.749	.054	5.42
Christian prospect No. 2[a]	Paul C. Bowers...	46.73	....	.476	.094	20.79
Christian prospect No. 3[a]	Paul C. Bowers...	51.94	....	1.233	.045	12.45
Nixon bank No. 1[a]	Paul C. Bowers...	47.07	....	.640	.042	18.42
Nixon bank No. 3[a]	Paul C. Bowers...	50.41	....	.320	.049	13.49
Nixon bank No. 6[a]	Paul C. Bowers...	53.69	....	.352	.002	9.10
Odom bank[a]	Paul C. Bowers...	48.50	....	1.071	.029	14.38
Nixon bank No. 8[a]	Paul C. Bowers...	43.84	....	.822	.05	20.42
Grinders bank[a]	Paul C. Bowers...	50.46	....	.841	.221	12.39
Nixon-Craig prospect[a]	Paul C. Bowers...	51.63	....	1.113	.036	10.87
Charlotte Lumber Co., prospect No. 2[a]	Paul C. Bowers...	50.9	....	1.422	.032	10.50
Charlotte Lumber Co., prospect No. 3[a]	Paul C. Bowers...	54.11	....	.732	.044	8.99
Charlotte Lumber Co., prospect No. 4[a]	Paul C. Bowers...	34.64	....	.688	.048	35.02
Brown prospect[a]	Paul C. Bowers...	36.3	....	.232	.086	34.22
Brush Creek prospect No. 3[a]	Paul C. Bowers...	54.08	....	1.916	.056	5.79
Allens Creek mines	Paul C. Bowers...	56.89	....	1.372	.007	4.21
Allens Creek mines	Paul C. Bowers...	53.86	....	1.39	.006	7.14
Allens Creek mines	Paul C. Bowers...	51.01	....	.64	.017	11.18
Percy mine	Paul C. Bowers...	51.01	....	1.247	.002	6.27
Percy mine	Paul C. Bowers...	49.85	....	1.417	.004	12.52
Wayne Furnace mines	Wuth & Safford..	52.28	....	.88	....	9.41
Wayne Furnace mines	Pittsburg Testing Laboratories....	50.86	1.49	.982	....	11.25
Wayne Furnace mines	Paul C. Bowers...	52.91	....	1.561	.015	7.30

(A) Specimen with polished surface from the Lee Hollow mines, 2 miles east of Wayne Furnace. Illustrates the replacement of chert (light-gray) by brown iron oxide (dark-gray). Natural size.

(B) Specimen with polished surface from East Furnace Ridge mine at Wayne Furnace. It illustrates the replacement of chert (light-gray) by brown iron oxide (dark-gray). Natural size.

Wayne Furnace mines	Paul C. Bowers...	53.55	....	.744	.021	11.90
Wayne Furnace mines	Paul C. Bowers...	54.52	....	.874	.01	9.11
Pinkney mine	Paul C. Bowers...	54.17	....	1.302	.004	6.01
Pinkney mine	Paul C. Bowers...	56.07	....	.361	.024	7.06
Gresham mine	Paul C. Bowers...	56.39	....	.788	.014	3.83
J. B. Powell mine	Sheffield Coal & Iron Co.	54.20	....	.80	....	6.00*b*
J. B. Powell mine	The Red River Iron Co.	55.60	....	1.02	....	4.20*b*
J. B. Powell mine	The Brown Laboratories	55.54	....	.80	....	4.36*b*
Seavy-Lull mine	Sloss-Sheffield Steel & Iron Co.*c*	49.76	....	.74	....	10.00*b*
Seavy-Lull mine	Sloss-Sheffield Steel & Iron Co.*c*	54.35	.48	.98	....	6.30*b*
Seavy-Lull mine	Sloss-Sheffield Steel & Iron Co.*c*	54.22	1.08	.92	....	4.90*b*
Seavy-Lull mine	Sloss-Sheffield Steel & Iron Co.*c*	54.55	.51	.64	....	7.25*b*
Seavy-Lull mine	Paul C. Bowers...	54.02	....	1.07	.014	6.98

*a*Rogers, Reese F., The iron ore deposits of Lewis County, Tennessee: The Resources of Tennessee, vol. 5, No. 3, pp. 91-146, July, 1915.

*b*Insoluble residue.

*c*Purdue, A. H., The iron industry of Lawrence and Wayne counties: The Resources of Tennessee, vol. 10, p. 384, 1912.

FORMS OF THE ORES

The ore occurs as simple veins, as a network of branching veins, and as large irregular masses, many feet long in their longest dimension, in the deeper parts of the openings, but occurs as loose disconnected fragments near the surface. (See Plate VI, B). The loose fragments near the surface vary in size from shot-like pieces to those 2 to 3 inches in diameter and have been formed by the breaking up of the veins and large masses by weathering. As the ore comes from the mines it consists of fragments of many sizes ranging from a fraction of an inch to several feet in diameter; the different sizes are known as shot, lump and boulder ore. The shot and lump ores occur near the surface and the boulder ore in the deeper parts of the workings, but at many places the boulder ore extends to the surface.

The ore is hard; much of it, especially the lump and shot ores, is compact, but much of it, especially the larger masses or boulder ore, contains many irregular cavities. (See Plates V, B; VI; and X). These large masses usually inclose clay and contain many fragments and pebbles of chert so that their silica content is high. The chert fragments may be sparsely scattered through the ore or they may be so numerous that they and the iron-cement form a breccia. The top fragmentary ores are better in quality as they contain less silica than the massive ores. The pebbly ore is usually a hard conglomerate.

A variety of ore, known as bomb shell ore, consists of angular hollow masses, as much as 1 foot or more in their longest dimension, which have shells of iron oxides 1 inch or less thick. (See Plate IX.)

OCCURRENCE OF ORE AND SIZE OF DEPOSITS

The iron ore, in the forms that have been described above, is irregularly distributed through the residual chert and clay of the St. Louis limestone and through the pockets and lenses of sand and gravel, most of which are of Cretaceous age. These, as previously stated, are more or less intimately mixed and all of them are present in many ore deposits.

The ore at most places reaches the surface though at some places it is overlain by barren material which ranges in thickness from a few feet to 30 feet. The thickness (vertically) of the ore-bearing material ranges from a few feet to 70 feet or more, and at most deposits that have been mined it has averaged between 15 and 35 feet. The deposits also have a fairly large areal extent and they lie in a horizontal or nearly horizontal position.

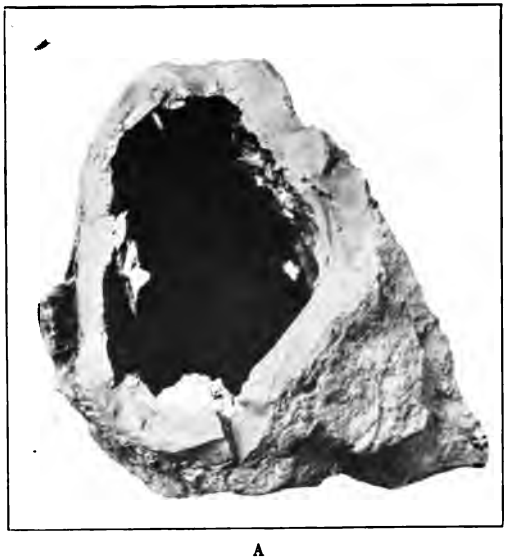
The deposits in some of the abandoned mines that were worked with steam shovels were considered to have been exhausted under the conditions that prevailed at the time the mines were abandoned. The areal extent of the deposits at these mines that were workable at such times therefore correspond to the area of the open cuts in which the ore was mined. Some if not all of the abandoned mines will however be reopened in the future and ore will be mined from both the bottoms and sides of the cuts.

The area of the cuts of the active and abandoned mines that have been worked by steam shovels ranges from less than 1 acre to 40 acres or more and the aggregate area of the cuts in the quadrangle is estimated by the writer to be about 250 acres.

The quantity of washed ore that has been obtained per acre in the Waynesboro quadrangle has ranged from about 4,000 tons to about 40,000 tons. Very few mines have however been worked that have had a production of less than 10,000 tons per acre. The average production per acre of all of the mines has been about 20,000 tons.

The ratio of ore to ore-bearing material or ore dirt varies not only from one deposit to another but also varies from place to place in the same deposit. Mining is said to show that in some deposits there is a larger proportion of ore in the centers of the ridges than on their sides. The highest ratio that has been found was 1 ton of washed ore for every 2 cubic yards of loose ore dirt but the average ratio of the ore that has been mined has probably been 1 ton of washed ore for every 4 yards of loose ore dirt. The lowest ratio that it has paid to work is not known but is probably not less than 1 to 10. In recent years, however, ore with such a low ratio could not be worked profitably.

Many of the worked deposits are called banks; but the term bank, as commonly used in the Waynesboro quadrangle, is applied to an iron-ore deposit irrespective of whether the deposit has been worked.



A

B

Specimen of bomb shell ore from the Lee Hollow mines, 2 miles east of Wayne Furnace.
(A) View showing a small amount of soft chert adhering to the inner surface of the specimen. One-third natural size.
(B) View showing angular shape of specimen. One-third natural size.

RESERVES OF ORES

Reserves of iron ore for the future occur at the mines that are now being worked, at some or all of the mines that have been abandoned and at the numerous deposits that have not been worked. An estimate of the total reserves is not here attempted but an estimate of the ore that is available at present and in the near future has been made. Some of the difficulties in making such estimates are as follows:

1. The prospecting that has been done at most deposits has not been extensive enough to furnish information for tonnage estimates. Furthermore such estimates can not be relied upon entirely because most experienced operators agree that no deposit can be safely estimated in advance of the complete mining out of the deposit.

2. Many deposits have been prospected very little or not at all and estimates of their size would be unreliable.

3. Many deposits are several miles from railroads, and therefore can not be worked now.

4. A large quantity of ore contains too much silica to be mined at present or in the near future.

5. The ratio of ore to ore-bearing material in some undeveloped deposits and in parts of some developed deposits is too low for the ore to be mined under present conditions. Some of this ore will, however, probably be minable in the future when conditions change.

The ore that is now available and the ore that will be available when the railroad from Collinwood to Wayne Furnace is completed is estimated by the writer to be 6,000,000 tons. The construction of this railroad has been begun and is well advanced toward completion which is expected to take place in the near future. The quantity of available ore will doubtless be found to be greater by prospecting more thoroughly the known deposits and by discovering new deposits. The above estimate is believed to be conservative. It was obtained by adding together the writer's estimate of the available ore at the different deposits. Some of the estimates at the different deposits that were so used correspond to the estimates of mining men, but some of them differ widely from the estimates of mining men. For example, one estimate by mining men is that there is 4,000,000 tons of available iron ore in one deposit; a second that there is 9,000,000 tons on one property, and a third that there is 10,000,000 tons on another property.

RELATION OF DEPOSITS TO SURFACE FEATURES

The iron-ore deposits, with very few exceptions, occur on the crests of the ridges or well up their slopes near their crests and but very few are more than 150 feet below the highest crests in their vicinity. Examples of deposits on the crests of the ridges are those at the Allens Creek, Percy, Wright, Ironsides, Pinkney, Couch, Van Leer, and Seavy-Lull

mines. The deposits that are below the crests are on the ends and sides of the ridges adjoining the valleys. Examples of these are at the East Furnace Ridge, West Furnace Ridge, Nigger Ridge, Lee Ridge, Murphy, Sapling, West, Dodd, and Robinson mines.

The crests of the ridges in the Waynesboro quadrangle attain a common level and are believed to mark the approximate elevation of a former, though now dissected, peneplain to which the name Highland Rim peneplain is applied. This peneplain has been dissected by the valleys of the present streams of the quadrangle which are as much as 300 feet deep. The iron-ore deposits being on or near the crests of the ridges are at or near the level of this peneplain.

The iron-ore deposits are all above the permanent ground water level but during rainy seasons water collects and stands in depressions in the open cuts.

OUTCROPS OF THE DEPOSITS

A good discussion of the outcrops of the iron deposits has been given by Rogers.[1] It follows:

"Outcrops vary greatly in size and form, and frequently indicate the nature and value of the deposits. Some outcrops will extend over less than ¼ of an acre, while others will occur more or less continuously over several hundred acres. However, in many cases the size and character of the outcrops are insufficient criteria upon which to base a reliable estimate of the size and value of a bank. Valuable deposits have been found to underlie areas showing little or no surface indications. In such cases more or less soil or gravel overlies the ore body. No doubt there are local segregations of ore many acres in extent that do not show at all or appear on the surface. Such deposits doubtless exist in the flat ridge lands where the soils have a considerable thickness, and in other favorable situations where erosion has lagged behind rock weathering.

"A promising form of outcrop consists of chunks of ore embedded in the soil with the surface of the ground strewn with either or both large and small fragments of ore, and the subsoil very red and containing a considerable quantity of shot ore. Other things must be taken into consideration, such as the depth of the material overlying the solid rocks, and the elevation and extent of the workable deposit.

"A less promising form of outcrop consists of a ledge of highly siliceous and massive conglomerated and brecciated ore protruding from the side of the hill or ridge. These ledges are sometimes 20 feet or more in thickness, and from a few feet to over 150 feet in length. The ore underlying such outcrops is usually of a very inferior quality, and of little or no commercial value at the present time."

USES OF ORES

The iron ore from the Waynesboro quadrangle has been used in making ferrophosphorus and the following varieties of pig iron: high-phosphorus, high-silicon, foundry, soft, hot blast charcoal, and cold blast charcoal.

ORIGIN OF THE ORES

The iron-ore deposits occur not only in the residual chert and clay

[1] Rogers, Reese F., The iron ore deposits of Lewis County, Tennessee: The Resources Tennessee, vol. 5, No. 3, p. 100, July, 1915.

of the St. Louis limestone, of Mississippian age, but also in pockets or lenses of sand and gravel which in most places are of Tuscaloosa (Upper Cretaceous) age. The sand and gravel were probably laid down by streams on an uneven surface of the St. Louis limestone and some was apparently deposited in limestone sinks and underground channels. Since Cretaceous time this limestone has weathered deeply in the Waynesboro quadrangle leaving a residue of chert and clay as much as 100 feet thick. The sand and gravel as they are found at present are therefore not associated with the St. Louis limestone but are associated with its residual chert and clay. All of these surficial materials have settled and caved to some extent during the weathering of the limestone and have thus become more or less intermixed. Their settling was brought about at most places by gravity but streams may have at places carried them from their original to their present position. Just how much settling has taken place can not be determined. It may have been 100 feet, 200 feet or more. In the Batesville district, Arkansas,[1] chert layers are known to have settled at least 250 feet as a result of the weathering of underlying beds of limestone.

The deposits and their inclosing materials are mostly on or near the crests of the ridges. The ridge crests in the Waynesboro quadrangle attain a common level and are believed to mark the approximate elevation of a former, though now dissected, peneplain to which the name Highland Rim peneplain is applied. This peneplain, according to most geologists, was formed during the Tertiary period and has been dissected since that period by the valleys of the present streams which are as much as 300 feet deep. Since the iron ore deposits and the materials that contain them are on or near the crests of the ridges they are at or near the level of the Highland Rim peneplain.

In a region of low relief such as that on a peneplain rock decay and solution would probably be more active than rock disintegration and removal whereas in a region with considerable relief rock decay and solution would be less important in comparison with rock disintegration and removal. It therefore appears probable that the deep weathering of the St. Louis limestone to form as much as 100 feet of residual materials took place in large part during the existence of the Highland Rim peneplain, though it has doubtless continued to some extent down to the present.

That much of the ore was deposited from iron-bearing solutions beneath the surface is supported by the facts (1) that a large part of the ore occurs in the residual clay and chert of the St. Louis limestone that have simply settled more or less by gravity since the removal of the calcium carbonate of the limestone, and (2) that a large part of the ore occurs as simple and branching veins not only in the residual chert

[1]Miser, H. D., Preliminary report on the deposits of manganese ore in the Batesville district, Arkansas: U. S. Geol. Survey Bull. 715-G, pp. 116-117, Nov. 15, 1920.

and clay of the St. Louis limestone but in the sand and gravel of later age. The ore in some deposits or in parts of some deposits that are in what appears to be alluvial material may however have been deposited from chalybeate waters of surface streams. Since the present ground water level and the present streams are lower than the iron ore deposits, it is necessary to assume that the deposits were formed in the past when the surface features were such as to cause the ground water and surface drainages to reach the areas in which the deposits occur. Such surface features occurred in the quadrangle during the existence of the Highland Rim peneplain when there was little relief with valleys perhaps not over 100 feet deep. It therefore appears that the iron-ore deposits were formed on the Highland Rim peneplain before the present deep valleys of the quadrangle were eroded.

This conclusion regarding the iron ores of the Waynesboro quadrangle accords with that of D. F. Hewett[1] for the formation of several manganese deposits in Virginia and Maryland. He expressed the opinion that conditions are especially favorable for rock decay and the concentration of manganese minerals in a region of low relief such as that occurring on a peneplain. His theory has been accepted and applied by other geologists[2] to the manganese deposits in the entire Appalachian region and in the Batesville district, Arkansas. He has also suggested that it applies to the brown iron ores of the Appalachian region, which are held by a number of geologists to have been formed during the Tertiary period. Concerning this subject he says[3]:

"It would be unwise without further study to assert that all the manganese deposits of Virginia or the region from Alabama to eastern Pennsylvania were formed during the early Tertiary period of erosion, but it is interesting to note that this suggestion was once made for the Appalachian deposits of iron ore, which have a similar areal distribution, as a result of the discovery of small basins of lignite of Tertiary age near Brandon, Vt.,[4] and Pond Bank, Pa.,[5] near deposits of iron ore. It was then thought however, that the residual iron ores within this entire region were the weathered residue of an essentially continuous horizontal iron-bearing bed. This assumption is not necessary, but it is reasonable to suppose that conditions during early Tertiary time may have favored, more than those of later periods, the solution and transportation

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[1]Hewett, D. F., Some manganese mines in Virginia and Maryland: U. S. Geol. Survey Bull. 640, pp. 43-47, 1917.

[2]Hewett, D. F., Stose, G. W., Katz, F. J., and Miser, H. D., Possibilities for manganese ore on certain undeveloped tracts in Shenandoah Valley, Virginia, U. S. Geol. Survey Bull. 660, pp. 271-296, 1918.

Stose, G. W., Miser, H. D., Katz, F. J., and Hewett, D. F., Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, 1919.

Hull, J. P. D., La Forge, L., and Crane, W. R., Report on the manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, 1919.

Miser, H. D., Preliminary report on the deposits of manganese ore in the Batesville district, Arkansas: U. S. Geol. Survey Bull. 715-G, 1920.

Miser, H. D., Manganese deposits of the Batesville district, Arkansas: U. S. Geol. Survey Bull. (in course of publication).

Stose, G. W., and Schrader, F. C., Manganese deposits of east Tennessee: U. S. Geol. Survey Bull. (in course of publication).

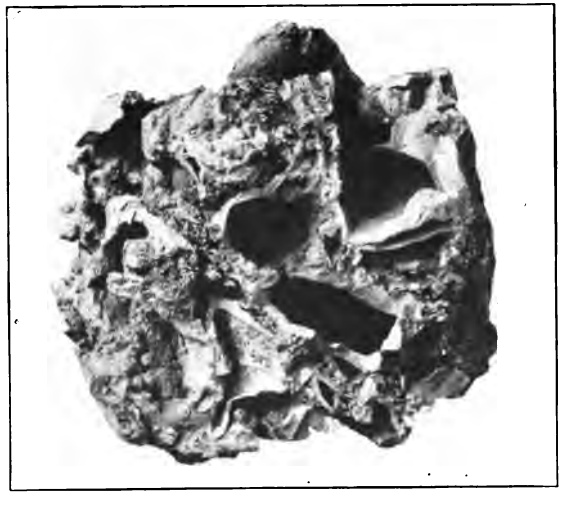
Stose, G. W., and Miser, H. D., Manganese deposits in the western part of the valley of Virginia: Virginia Geol. Survey Bull. (in course of publication.)

[3]Hewett, D. F., Op. cit., pp. 46-47.

[4]Hitchcock, Edward, Description of a brown coal deposit at Brandon, Vt., with an attempt to determine the geological age of the principal ore beds of the United States: Am. Jour. Sci., ser. 2, vol. 15, p. 95, 1861.

[5]Lesley, J. P., Lignite in iron ore at Pond Bank, Franklin County, Pa.: Am. Philos. Soc. Proc., vol. 9, pp. 463-482, 1864.

(A) Brown iron ore, containing irregular cavities, from the Wisdom mine, 2 miles northeast of Pinkney. Half natural size.



(B) Brown iron ore, containig irregular cavities, from the Robinson (White-Littrell) mine, 2 miles south-west of Corning. Two-thirds natural size.

of iron and manganese salts to favorable sites for deposition. The existence of many extensive deposits of residual iron ore and related laterite in regions having warm and moist if not tropical climates has long been recognized. In this connection it may be noted that Berry,[1] as a result of the study of the floras of the Upper Cretaceous and Eocene formations of the Coastal Plain of South Carolina and Georgia, concludes that the prevailing climate of that region at the time these beds were laid down was mild and humid, with possibly a brief period during Eocene time that was less mild.

"Spencer[2] has noted that the large deposits of brown hematite of Mayari, in the Province of Oriente, Cuba, underlie an extensive rolling plain that is regarded as a remnant of a peneplain, possibly of late Tertiary age."

E. C. Eckel in discussing the origin of the brown ores of the Birmingham and Russellville districts in Alabama made the following statements in 1910:[3]

"It must be accepted as at least highly probable that the bulk of our brown-ore deposits were formed during the Tertiary.

"Three lines of evidence are available which enable us to place this relatively narrow limit on the main period of brown-ore formation. They are:

"1. It is readily demonstrable, with respect to the majority of the deposits, that they were formed after all the folding of the region had been accomplished. * *

"2. Many brown-ore deposits can be proved, and most others may be inferred, to have existed at the beginning of the glacial period in the north. * * * * * *

"3. Direct evidence as to the age of a very few ore deposits is afforded by the inclusion or association of Tertiary fossils with them.

"In the Russellville district, Alabama, there is, fortunately, rather definite proof that the brown-ore deposits were in existence, in substantially their present location, form, and size, during late Tertiary time. This proof is afforded by the relation which the red loam and gravel (late Tertiary)? of the region bears to the underlying and adjacent brown-ore deposits.

"This is best brought out on examination of some of the older workings, about midway between the present Sloss-Sheffield openings and Russellville. In these workings the red loams are seen to overlie directly the brown ores and their associated clays. At the base of the reddish loam, a pebble bed occurs. This varies in thickness from a few inches to several feet. Most of the pebbles are rounded quartz and chert * * Along with these, however, are many smooth-surfaced but more angular fragments of brown iron ore. These have evidently been derived directly from the near-by beds of brown ore, and consequently these brown-ore beds must have been in existence, in practically their present form, during the deposition of the red loam and gravel."

The above-mentioned age relations of the iron ores of the Russellville district were observed by E. F. Burchard[4] in 1906 and were described by him in 1907.

The source of the iron ore is not known but is believed to have been either the St. Louis limestone or rocks of Upper Cretaceous age or both. The St. Louis limestone, as previously stated, has weathered deeply in the Waynesboro quadrangle leaving as a residue chert and clay

[1]Berry, E. W., The Upper Cretaceous and Eocene floras of South Carolina and Georgia: U. S. Geol. Survey Prof. Paper 84, pp. 122-158, 1914.

[2]Spencer, A. C., Three deposits of iron ore in Cuba: U. S. Geol. Survey Bull. 340, p. 318, 1908.

[3]Eckel, E. C., in Burchard, E. F., Butts, Chas., and Eckel, E. C., Iron ores, fuels, and fluxes of the Birmingham district, Alabama: U. S. Geol. Survey Bull. 400, pp. 149-150, 1910.

[4]Burchard, E. F., The brown iron ores of the Russellville district, Alabama: U. S. Geol. Survey, Bull. 315, pp. 152-160, 1907.

which are as much as 100 feet thick. Whatever pyrite and other iron minerals may have occurred in the limestone were oxidized during the weathering of the limestone and may have contributed their iron for the formation of the present iron ores. Very little is known concerning the character of the St. Louis limestone in this area because it is concealed almost everywhere by its residual chert and clay and by the Tuscaloosa gravel. In the few exposures of the St. Louis little or no iron minerals were observed.

The Tuscaloosa gravel and Eutaw sand, of Upper Cretaceous age, cap the ridges in the southwest part of the quadrangle and the Tuscaloosa is present on most of the ridges in the other parts of the quadrangle. It is therefore reasonably evident that the Tuscaloosa and perhaps the Eutaw at one time extended as continuous beds over the quadrangle. Iron oxide forms a cementing material in the Tuscaloosa gravel at numerous places and the gravel that is thus cemented together has become a hard conglomerate. Such conglomerates are especially abundant at or near the base of the Tuscaloosa. They are very resistant and form projecting ledges. One such ledge near Stout in the southwest corner of the quadrangle is 30 feet thick and forms a bluff of that height. The occurrence of this iron cement in the gravel indicates that the gravel or Eutaw or higher beds are the source of the iron and that they may have been the source of the iron for the brown iron ores of the Waynesboro quadrangle.

The porosity of the residual clays and cherts of the St. Louis limestone made an easy roadway for the movement of the iron solutions and the deposition of the ores. The pockets of sand and gravel some of which were apparently deposited in underground channels also probably influenced to a certain extent the deposition of the ores.

The occurrence of many of the deposits at the ends and sides of the ridges adjoining the present valleys also suggests that the iron solutions were diverted into shallow valleys. At that time, as at present, the drainage lines were doubtless somewhat influenced by the rock structure, with the streams occupying the synclinal axes or troughlike depressions of the folds. According to the above view the greater part of the ores were probably eroded during the cutting of the present deep valleys of the quadrangle.

METHODS OF PROSPECTING, MINING, AND CONCENTRATING THE ORES

The primitive methods of mining and concentrating the ores as used from 1832 to 1875 are described under the headings Wayne Furnace mines (pages 79 and 81) and Van Leer mine (page 109). Only the present or modern methods are here described.

The iron ore deposits have been prospected to a small extent by drilling and by making trenches but they have been prospected at most places by sinking wells or round pits to a depth of as much as 50 feet.

Such pits are usually sunk at irregular intervals over the ore-bearing tracts. A better method which has been followed at a few places is to sink them at regular intervals of 200 feet or less apart. Experienced miners of brown ore have found that it is good economy to test thoroughly a piece of ground before any mining is begun, and that it is likewise advisable to push prospecting for some distance beyond the point where an ore body terminates. The value of a detailed topographic map in connection with prospecting of brown ore, as well as in later development work, can not be overestimated. It is an expensive form of mapping but it has been found to be a true economy where large developments are planned. Such mapping has been done at a few of the ore deposits in the Waynesboro quadrangle.

The mining of the iron ore is done in open cuts and most of it is done with steam shovels. (See Plates IV, B and VI, A). At only a few places has ore been mined by hand since 1887 when the period of extensive iron mining in the quadrangle began. The mining is usually begun in the sides of the hills and near their crests and, although the cuts are above the permanent ground water level, rain-water collects and stands in depressions that are made in them. Some deposits, such as several of those at and near Wayne Furnace, may require underground mining in connection with open-cut mining on account of the presence of as much as 30 feet of overburden.

The ore-bearing dirt is hauled by locomotives to the washing plants. The equipment of all the plants is not the same though most of them are provided with log washers, jigs, screens and picking belts and some have crushers. Most of the clay and most of the smaller fragments of chert are removed by means of log washers and jigs; the larger fragments of chert are removed by hand from a picking belt. It is, however, not possible to remove all of the chert and clay, and as a result the silica content of the ore as it comes from the washing plants is high, averaging about 15 per cent. Ore-bearing material with loose pebbles in it is avoided in mining because the jigs are unable to separate the pebbles from the ore. The ore that occurs in lenses and pockets of sand incloses much sand and is not mined because the sand can not be removed from the ore.

A sufficient supply of water for the plants is obtained from the creeks and rivers and is pumped as far as 2 miles. The water after it passes through the plants is red in color and contains much clay, sand, and fine ore. It runs from the plants into ponds where these materials settle.

Standard-gauge railroad spurs are run from the main railroad lines to the washing plants and the washed ore is loaded from the bins directly into freight cars.

The climate is generally favorable for mining through the entire year as the ground seldom freezes sufficiently to hinder it or to prevent washing the ore.

MINES AND PROSPECTS

Morton Property (1)[1]

The Morton property, owned by S. D. Morton and other persons, is in the northeast corner of the Waynesboro quadrangle, northwest of Grinders Creek and 6 miles northeast of Riverside. It was not visited by the writer. Rogers[2] describes it as follows:

"This property is located 4¼ miles S. 35° E. of the post-office at Hohenwald, and ½ mile northwest of Morton's house. The surface showings consist of an occasional boulder and a few fragments of limonite sparingly distributed over the slopes of several spurs of a ridge and around the heads of several hollows. Some of the ore seen was of excellent quality, especially the pot ore. Most of the ore found was in old fields. A sample of float ore analyzed 56.36 per cent. iron; 5.42 per cent. silica; .749 per cent. phosphorus; and .054 per cent. sulphur."

Christian Prospect No. 1 (2)

The Christian prospect No. 1, owned by H. T. Christian, is on the north edge of the Waynesboro quadrangle, 3¼ miles northeast of Nancy. Rogers[3] supplies the following description of it:

"This deposit, located 3½ miles S. 12° E. of the post-office at Hohenwald, is situated on the south slope to a shallow hollow, on the spur of a ridge near its crest. It is near the head of Rush Branch, and about 2 miles northwest of its mouth.

"The outcrop covers an area of nearly an acre. It consists of boulders protruding through the clay soil and of small fragments scattered over the surface. Three shallow pits, ranging from 3 to 4 feet in depth, have been dug within the area of the outcrop. Two pits are on the slope of the spur, and the other one is in the hollow near its base. All the pits show some ore, and one a considerable quantity. The last clay thrown out of the two upper pits is very red. The ore is a fair quality of limonite."

Christian Prospect No. 2 (3)

The Christian prospect No. 2, owned by H. T. Christian, is described by Rogers[4] as follows:

"This bank prospect is one mile N. 38° W. of the junction of Grinders Creek Buffalo River. The deposits are situated on the top and slopes of a high southeast spur of a secondary ridge. The ridge has an elevation of 900 feet above sea level, and its crest is nearly 200 feet above Grinders Creek.

"The deposits occur in red clay with which is associated more or less angular chert and sometimes water-worn gravel. Bedded rocks are exposed on the northeast and east slope of the ridge near its base. A 40-foot section of cherty limestone was observed near the mouth of Rush Branch. As the top of this section is approximately 125 feet below the crest of the ridge, it appears that the detritus overlying solid rock is quite thick.

"The outcrop extends over an area of 12 to 15 acres. It is composed of boulders and fragments embedded in the soil and scattered over the surface. On a large part

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[1]Numbers refer to location on map (in pocket).
[2]Rogers, Reese F., The iron ore deposits of Lewis County, Tennessee, Resources of Tennessee, vol. 5, No. 3, p. 127, July, 1915.
[3]Rogers, Reese F., op. cit., p. 127.
[4]Rogers, Reese F., op. cit., pp. 127-128.

of this area, especially on that south of the road, the ground is thickly strewn with ore. There are boulders over 5 feet in diameter, some of which appear heavy with iron, but others are light and contain a large per cent. of chert. A mass of highly siliceous ore extends along the south face of the spur for a distance of 75 feet, about 40 feet below its crest. Twenty shallow test pits have been dug within the area of the outcrop. Eight are located on the north side of the road, and 12 on the south side. Six of those on the north side of the road are nearly blank, and the 2 remaining ones make a fair showing. Of the 12 pits on the south side of the road 7 show very little ore, 4 make a fair showing, and one an excellent showing. The last material removed from the pits is generally of a deep red color, but some of the very shallow ones do not show any very red clay. This material often has a large quantity of shot ore mixed with it, and angular chert is frequently abundant, but comparatively little water-worn gravel was noticed.

"Much of the ore is siliceous, silica occuring principally as embedded chert and sometimes in the form of sand; but the percentage of siliceous material varies largely, portions of the ore being almost free from it, while the amount in other portions runs very high. The ore occurs in both the cellular and compact forms. Relatively little pot ore was seen, and most of it being of the solid chunk variety. Some limonite cemented sandstone was observed. A representative sample taken from the dumps analyzed 46.73 per cent. iron; 20.79 per cent. silica; .476 per cent. phosphorus; and .094 per cent. sulphur.

"The test pits and surface showings indicate that deposits of ore occur over an area of at least 10 or 12 acres. The depth to which the ore extends is not known, but the residual outcrops 40 feet below the crest of the spur indicate that ore extends to at least that depth."

Christian-Floyd and Adjoining Property (4)

This property which is owned by H. T. Christian, Henry M. Floyd, C. R. Brown and others is described by Rogers[1] as follows:

"That part of the property showing ore is practically a continuation of the Christian Bank prospect No. 2, already described, and is located on a northeast spur of the same ridge.

"In the road on the northeast slope of the spur, there are some spots that have a very red clay soil. Shot ore is abundant in the clay, and a few hundred feet north of this place lumps of siliceous ore are distributed over the surface and protrude through the clay of the road. Similar indications occur sparingly around the heads of several draws on this spur."

Christian Prospect No. 3 (5)

The Christian prospect No. 3, owned by H. T. Christian, is described by Rogers[2] as follows:

"This bank prospect is located 2¾ miles N. 45° E. of Riverside, or 1½ miles east of Nancy. It is situated on the top of a ridge, at an elevation of 900 feet above sea level. On and near the point of a northeast spur of the ridge 11 test pits have been dug. Their depth varies from 2 to 3½ feet, which is entirely too shallow for test purposes. Only 2 of the 11 holes showed a fair quantity of ore, and most of the others are blank or nearly so. Seven holes were found on the southeast extension of the main ridge, and between this place and the one previously described, 5 more pits occur. These pits are also very shallow, for their average depth is only about 3 feet. Six make a fair to excellent showing of ore, and 1 a poor showing. Some of the 5 re-

[1]Rogers, Reese F., op. cit., p. 128.
[2]Rogers, Reese F., op. cit., pp. 128-129.

maining ones show more or less shot ore, and others are blank. The surface showings at this place extend over 8 to 10 acres.

"The outcrops extend over a total area of possibly 10 or 20 acres and at certain places, the surface is thickly strewn with large and small fragments of limonite. Some of these are buried in the clay soil, while others are loosely distributed over the ground. A few of the boulders are more than 2 feet in diameter, but large chunks of ore are rare. The outcrops consists mostly of shot ore. Some of the root-wads show a large quantity of ore. No exposures of stratified rock were found in the vicinity of the bank.

"The ore occurs in red clay containing chert fragments, which are often very abundant. The surface showings between the two main outcrops and the few shallow pits, indicate that ore would probably be encountered by sinking deep shafts on the higher lands located on and near the crest of the ridge.

"Much of the ore seems free of excessive chert, gravel, and sand, but some is quite siliceous. The ore is found in both the cellular and compact forms. An average sample from 11 shallow pits analyzed 51.94 per cent. iron; 12.45 per cent. silica; 1.233 per cent. phosphorus; and .045 per cent. sulphur."

Jacks Branch-Rockhouse Creek group

General features—The Jacks Branch-Rockhouse Creek group comprises the following banks: Nixon banks Nos. 1 to 8 owned by the Henry Nixon heirs, Centerville, Tenn.; the Odom bank owned by Dempse Odom, Hohenwald, Tenn.; and the Grinders bank owned by J. C. Grinder, Hohenwald, Tenn. This group has been described by Rogers[1] from whom the following is quoted:

"The Jacks Branch-Rockhouse Creek group, * * * is situated on a high ridge and its spurs, between Jacks Branch and Rockhouse Creek. It has a north and south trend and an elevation ranging between 900 and 1000 feet above sea level, the crest being 200 to 250 feet higher than Jacks Branch.

"The ore is found in pockets in the clay, gravel, chert, and other loose material overlying the St. Louis formation. No outcrops of bedded rocks were seen in the immediate vicinity of the banks, but such rocks are exposed on the lower slopes of the ridge. The loose material is probably thick. Water-worn quartz and chert gravels are more or less abundant on the top of the main ridge and its spurs, especially on the main ridge, where these gravels in places, appear to have a thickness of over 15 feet. Most of the outcrops occur on the spurs. Nearly all the test pits are very shallow, and afford little knowledge regarding the size and depth of the deposits. * * *

Nixon Bank No. 1 (6)—"This bank is on the southwest spur of the ridge, near Jacks Branch, and 4/5 of a mile N., 8° E. of McLean. Residual ore occurs over an area of 8 to 10 acres. Massive ore and boulders protrude through the clay on the west slope of the ridge, and some of these occur more than 30 feet below the top.

"Fifteen pits have been sunk on the top and slopes of the spurs, and these are distributed over an area of about 5 acres. Some have been dug where there is apparently little or no surface showings. The pits range from 2 to 30 feet in depth. About 25 per cent. of them make an excellent showing of ore, 50 per cent. a poor to fair showing, and 25 per cent. are blank. The clay in most of the pits is very red, and is sometimes rich with shot ore. The material from the pits is composed mainly of clay which contains some angular chert, and frequently water-worn gravel.

"The test pits and outcrops indicate that at least 10 acres are ore-bearing, and that the ore extends to a depth of 30 feet or more. It often shows particles of chert and frequently grains of sand, but much of the limonite is of good quality. The ore

[1]Rogers, Reese F., op. cit., pp. 134-139.

occurs in the compact forms and as pots. A representative sample analyzed 47.07 per cent. iron; 18.42 per cent. silica; .640 per cent. phosphorus; and .042 per cent. sulphur."

Nixon Bank No. 2 (7)—"This outcrop is situated on a spur a short distance north of and adjoining the Nixon Bank No. 1. The outcrop consists of a few fragments and small boulders scattered over perhaps 2 acres, and the ore seems to be of about the same character as that occurring in the Nixon Bank No. 1."

Nixon Bank No. 3 (8)—"This bank, located 1 mile N. 30° E. of McLean, is situated on a south spur of the main ridge. The outcrop consists of small fragments, and an occasional boulder of brown ore over a nearly circular area of 4 or 5 acres. It has been prospected by 4 pits ranging from 2 to 10 feet in depth. The pits are about 140 feet apart, and occur at different elevations on the spur. All show more or less ore in red clay. Three others have been sunk on a narrow part of the spur, northwest of this outcrop, near the main ridge. These are shallow, and show chiefly water-worn gravel and angular chert.

"The ore is a light to dark-brown limonite and frequently contains some fine sand and small, irregular flakes of decomposed chert, but, on the whole, seems free of excessive siliceous impurities. It is of both the cellular and compact types. A typical sample analyzed 50.41 per cent. iron; 13.49 per cent. silica; .320 per cent. phosphorus; and .049 per cent. sulphur."

Nixon Bank No. 4 (9)—"The outcrop is situated on a south spur of the ridge about 1000 feet north of the Nixon Bank No. 2. At this place residual limonite is exposed at intervals over an area of 2 acres."

Nixon Bank No. 5 (10)—"The outcrop is about 900 feet northwest of Nixon Bank No. 4, and is situated on a north spur of the ridge opposite the latter bank. At this location residual brown ore occurs sparingly over an area of 5 acres."

Nixon Bank No. 6 (11)—"This bank is 1 1/5 miles N. 35° E. of McLean, and is on the southeast spur of the main ridge. Outcrops extend over an area of approximately 17 acres, parts of which are thickly covered with fragments of brown ore, but in most places, the showing consists of only a few scattered fragments. Some boulders 2 feet in diameter were found on the point of the spur. Many of the large fragments and most of the boulders are embedded in the soil.

"The ore is light to dark-brown in color and varies in texture from compact to cellular. Silica is present chiefly in the form of small particles, and these inclusions frequently have a flaky aspect. A surface sample analyzed 53.69 per cent. iron, 9.10 per cent. silica; .352 per cent. phosphorus; and .002 per cent sulphur."

Nixon Bank No. 7 (12)—"On the main ridge northwest of the above described outcrop about 25 very shallow test pits were found. They occur at different elevations on the ridge, but most of them are on the slopes less than 30 feet below the crest. These pits vary from 2 to 4 feet in depth, and only a few showed any ore, but this is to be expected from the shallowness of the pits. The material taken out is mainly clay, which contains an abundance of water-worn quartz and chert gravels and more or less angular chert fragments. It thus appears that there is a considerable thickness of gravel on top of the ridge at this place. This locality is west of and between the spurs where the outcrops of previously described banks occur, but here the exposures consist of only an occasional fragment, and some shot ore. The pits are scattered over an area of 25 acres, and have been dug where there are little or no surface indications. The ore seen was a light-brown or liver-colored limonite, and generally highly siliceous, though the quality might improve with depth.

"On the main ridge, about 3/5 of a mile north of this place, 20 or more pits were found on both sides of the road. This locality is between the Grinder and Odom banks. These pits are also very shallow. A few showed a little ore, but most of them are blank, as would be expected from their small depth. They have been dug where there are

little or no surface showings, but residual ore outcrops around the heads of several hollows in the immediate vicinity. The pits usually show a large amount of water-worn gravel and some angular chert in the clay. A part of this locality is described under the Nixon Bank No. 7, which adjoins it.

"From the preceding statements it is quite evident that if ore in quantity exists at either of these localities, deep shafts will have to be sunk to find it. The detritus overlying solid rocks is probably thick, and outcrops of bedded rocks do not occur in the immediate vicinity."

Odom Bank (13)—"This bank, located 1 2/5 miles N. 28° E. of McLean, is situated on an east spur of the main ridge, * * * . The bank is marked by an outcrop of limonite in the form of a few boulders, lumps, and small fragments occuring here and there over an area of 8 to 10 acres. Some of the ore is embedded in the clay, but most of the exposures are loose residual fragments. The ore is quite abundant on portions of the south and southeast slopes of the spur, near its point.

"A mining company is reported to have offered to prospect the bank, but as yet no test pits have been dug. The value of the property can not even be approximately determined from the surface showings alone, which extend west into the Nixon property.

"The ore is a light to dark-brown limonite, which has a texture varying from closely compact to coarsely cellular. The ore is frequently somewhat siliceous, which is chiefly due to embedded chert, for very little sand and quartz were visible in any of the specimens examined. An average surface sample of the ore analyzed 48.50 per cent. iron; 14.38 per cent. silica; 1.071 per cent phosphorus; and .029 per cent. sulphur."

Nixon Bank No. 8 (14)—"This bank is located 1¾ miles north of McLean and 1¼ miles northwest of Grinders mill. It is on and near the crests of the main ridge and several of its secondary ridges and their spurs.

"Iron ore, in the form of boulders and fragments embedded in the clay soil and scattered over the surface, is exposed at intervals over an area of 450 acres, within which the test pits have been dug. The outcrops cover an area varying from a few square yards to several acres, and are most abundant on the points and slopes of the ridges and spurs where the soil has been largely removed by wash. Residual ore was found in the bottoms of several of the shallow hollows, on the lower slopes of some of the ridges and in shallow pits, more than 60 feet below the crest of the main ridge. An occasional lump of ore and shot ore can be found over nearly the entire tract.

"Developments consist of more than 66 test pits scattered in groups over the area. These range from 2 to 7 feet in depth. As a rule, the holes have been dug where the surface showings are most abundant. Thirty-eight pits show more or less ore and 28 are blank or show only a little shot ore. Nine of the 38 show a large amount of ore, 21 fair quantity, and 8 make a poor showing. The blank holes are on or very near the top of the ridges, and the material removed from these is mainly water-worn and a light colored clay often containing angular chert fragments. The material is frequently nearly all gravel, thus suggesting that, at least on the crest of the ridges, a rather thick blanket of gravel overlies the ore deposits. The last material removed from those pits that show ore consists of red clay, angular chert, and sometimes water-worn gravel.

"The ore has a dense to coarsely cellular texture, but usually occurs in the compact form. The color of the limonite varies from light-brown or liver color to dark-brown or nearly black, on fresh surfaces. It is siliceous, and some of it highly so. The chief siliceous impurity is decomposed white chert which occurs in the form of small fragments and flaky particles incorporated with the ore. Small grains of sand are sometimes present, but large amounts of sand and quartz were not often noticed in any of the ore examined. Some of the dark-brown ore is nearly free of silica, and

this is evidently of excellent quality. The quality may improve with depth. A representative sample taken off the dumps of the 38 pits analyzed 43.84 per cent. iron; 20.42 per cent. silica; .822 per cent. phosphorus; and .05 per cent. sulphur.

"A close examination of this bank warrants the conclusion that many deep shafts will have to be sunk before any opinion can be formed regarding the value of the property. The prospecting already done is superficial and of little value. However, the test pits and outcrops indicate that deposits of ore doubtless exists over a large portion of the area, and to a depth of perhaps 60 feet. No outcrops of bedded rocks were seen, and the residuum may be quite thick."

Grinders Bank (15)—"This bank is located 1 4/5 miles N. 25° E. of McLean, and is on an east spur of the main ridge. The elevation of the spur ranges from 950 to nearly 1000 feet above sea level, and its crest is over 200 feet higher than Grinders Creek.

"Rocks are exposed in the bed of a small stream on the south slope of the spur, near its base, and about 150 feet below its crest. The loose material evidently extends to a considerable depth, on the crest of the spur. Residual iron ore occurs on portions of 10 or 12 acres. The showing consists of boulders, lumps, and small fragments, the best ones being on the point and south and east slopes of the spur.

"The bank has been prospected by nearly 40 test pits, which are scattered over an area of 8 acres. Most of the pits range from 3 to 12 feet in depth, and a few are 15 feet deep. The pits occur at different elevations, but most of them are on the south slope and point of the spur at less than 30 feet below the top. One deep shaft (partly filled with water at the time visited) is reported to show ore at the bottom, and to have encountered some ore throughout the greater portion of its depth of 47 feet. About 40 per cent. of the pits show a fair to large quantity of ore, 35 per cent. make a poor showing, and 25 per cent. are blank or nearly so. The pits that are nearly blank show only a little shot ore. The ore occurs in very red clay. Angular chert and sometimes water-worn gravels occur in the clay.

"Much of the ore is a dark-brown limonite of apparently good quality, for excessive amounts of siliceous matter is not visible in most of this ore. However, some of it is siliceous, which is due chiefly to embedded chert, although sand and small chert pebbles occur. The ore occurs mostly in the compact forms, but pots and other types are met with.

"This bank deserves systematic prospecting and possibly development. It extends over into the adjoining Nixon property, but nearly all the pits have been put down on that part of the spur owned by J. C. Grinder. More and deeper pits should be dug, and these should be more evenly distributed. Other portions of the spur should be thoroughly prospected. An average sample taken from several pits analyzed 50.46 per cent. iron; 12.39 per cent. silica; .841 per cent. phosphorus; and .221 per cent. sulphur."

Nixon-Craig prospect (16)

The Nixon-Craig prospect is owned by the Henry Nixon heirs, Centerville, Tenn., and Mrs. H. Craig, Riverside, Tenn. It is described by Rogers[1] as follows:

"This bank prospect located 3/5 of a mile N. 30° W. of Nancy, is situated on and near the top of a southeast spur of a main ridge. The spur has an elevation of between 900 and 950 feet above sea level, and its crest is nearly 250 feet higher than Rockhouse Creek. The main ridge has a north and south trend, and its elevation ranges from 900 to 1000 feet above sea level. No exposures of bedded rock occur, and the detritus overlying solid rock is probably thick on the crest of the spur and the main ridge.

[1]Rogers, Reese F., op. cit., pp. 139-140.

"The outcrop consists of small fragments and a few boulders of brown ore scattered in patches over an area of about 8 acres. These are very abundant on a portion of the Craig property, and occur around the head of a draw. Ten shallow test pits have been dug on the crest of the spur, distributed over an area of 5 or 6 acres. The pits vary in depth from 2 to 6 feet. Six of the 10 pits show a poor to fair quantity of ore, and the 4 remaining holes are blank. The ore occurs in cherty clay, some of which is of a very red color, and frequently is rich with shot ore.

"The ore is a light to dark-brown limonite, which generally occurs in the compact form. Some of it is cherty, but some is of good quality. The prospecting has not been thorough and the acreage of ore-bearing property is not known. An average sample taken from several pits analyzed 51.63 per cent. iron; 10.87 per cent. silica; 1.113 per cent. phosphorus; and .036 per cent. sulphur."

Charlotte Lumber Company prospects

Four prospects on the property of the Charlotte Lumber Co. of Charlotte, Michigan, are described by Rogers[1] as follows:

Prospect No. 1 (17)—"This prospect is located 3/5 of a mile northwest of the junction of Sweetwater Branch with Trace Creek. At this place, compact boulders of limonite occur in the bottom of a draw between two spurs of a ridge, and on the slopes to the hollow. The ore protruding from the slopes is 15 feet above the bed of a small stream, and is evidently in place. It appears that the stream has cut through an ore pocket. The outcrop is small, but the ridges were covered with leaves at the time the prospect was visited, so that other outcrops could not have been easily seen even if present. There are doubtless other occurrences of ore in this vicinity. The region has never been prospected."

Prospect No. 2 (18)—"This prospect is 4 miles N. 15° W. of Riverside, and ¾ of a mile east of the junction of Sweetwater Branch with Trace Creek. It is situated on the southwest slope and the point of a high secondary ridge. The crest of the ridge is over 250 feet above Trace Creek and has an elevation of between 950 and 1000 feet above sea level.

"The principal outcrop consists of compact boulder ore, embedded in the soil on the southwest slope of the ridge at approximately 30 to 35 feet below the top. This outcrop covers an area of 1 acre. Besides the main outcrop, there are isolated boulders and small lumps distributed over an area of 6 or 7 acres on and near the point of the ridge. The clay adhering to the roots of several fallen trees contains shot ore and sometimes larger fragments. This ridge seems to be covered by a rather thick soil mantle. The north slope has a deeper soil than the southwest one. Comparatively little angular chert and gravel was noticed on the ridge or in its vicinity.

"The surface showings are fair over about 4 acres, and there are at least 4 to 6 acres more on which the surface indications are more or less favorable, thus making a total of 8 or 10 acres over which pockets of ore may be expected to occur. The ore extends to a depth of at least 30 feet, for it is exposed at that distance below the crest of the ridge. Deep pits are necessary to test the property. Most of the ore is of fair quality, but some of it is very siliceous, due chiefly to chert inclusions. An average sample taken from the outcrop analyzed 50.9 per cent. iron; 10.50 per cent. silica; 1.422 per cent. phosphorus; and .032 per cent. sulphur."

Prospect No. 3 (19)—"This prospect, located 4¼ miles N. 53° W. of Riverside, is situated on and very near the crest of a high, chert-covered, secondary ridge, with an elevation of 900 feet above sea level, and about 250 feet higher than Sweetwater Branch. Large boulders and many small fragments of iron ore outcrop over an area of several acres around the head of a hollow, near the crest of the ridge. About 1000

[1]Rogers, Reese F., op. cit., pp. 132-133.

feet southwest of this place and on the opposite or south slope of the ridge, near its point, is another small outcrop of the same character of ore. Both outcrops consist of ore embedded in the clay soil and also strewn over the surface. Lumps of ore and shot ore occur sparingly between the two principal exposures. The slopes and top of the ridge are strewn with angular chert fragments, some of which have a fresh appearance. These suggest that bedded rocks of the St. Louis formation are comparatively near the surface, though no outcrops were observed on any of these ridges.

"The ore is a light brown limonite and is often quite siliceous. Many of the boulders contain decomposed chert and some gravel, while others are nearly free of foreign material. This locality has never been systematically prospected, and there are probably other iron ore outcrops in this vicinity. A representative sample taken from the outcrop analyzed 54.11 per cent. iron; 8.99 per cent. silica; .732 per cent. phosphorus; and .044 per cent. sulphur."

Prospect No. 4 (20)—"This outcrop of ore is in the extreme southwest corner of Lewis County, 6½ miles N. 60° W. of Riverside. The ore exposure is on the point of a spur of a secondary ridge, and covers an area of about 300 square yards. It consists of large and small chunks embedded in the soil, and float ore. Most of it is very cherty. A surface sample taken from the outcrop analyzed 34.64 per cent. iron; 35.02 per cent. silica; .688 per cent. phosphorus; and .048 per cent. sulphur."

Christian prospect No. 4 (21)

The Christian prospect No. 4 owned by H. T. Christian is described by Rogers[1] as follows:

"This deposit, located 1 3/5 miles N. 50° E. of Riverside, is situated on the top of a secondary ridge, which is on the east side of Piney Hollow. That part of the ridge where the ore occurs has an elevation of between 850 and 900 feet above sea level, and is about 250 feet higher than Buffalo River.

"Boulders and fragments of limonite occur over an area of 5 or 6 acres. Some of the ore is embedded in the soil, but most of it is loosely distributed over the surface. Chert fragments are abundant on the top and slopes of the ridge. Boulders of cherty ore and lumps of good ore were found on the side of the ridge 20 feet below the top. Two shallow pits have been dug, both of which show some ore in red clay. The ore from one of the pits is very cherty, but a fair quality was removed from the other. Most of the ore seen at this bank was rather siliceous, chiefly due to embedded chert."

Rochell-Slayton prospect (22)

The Rochell-Slayton prospect owned by M. R. Rochell, Hohenwald, Tenn., and T. J. Slayton, Clarksville, Tenn., is described by Rogers[2] as follows:

"This bank prospect, located 1 1/5 miles N. 35° E. of Riverside, is situated on a secondary ridge on the west side of Piney Hollow. The bank lies about 75 feet below the crest of the main ridge, and the elevation is about 825 feet above sea level, or between 200 and 250 feet above Buffalo River. The outcrop extends over an area of possibly 5 acres, and consists of an occasional boulder embedded in the soil and of smaller pieces of ore scattered over the surface. Within this area 6 test pits have been dug, ranging from 2½ to 4½ feet in depth. Only one of the pits shows any marked amount of ore, but most of the holes show considerable shot ore in very red clay. Some of the ore is very cherty, but that of good quality also occurs. Surface indications were noticed at several points north of here, near the crest of the main ridge."

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[1]Rogers, Reese F., op. cit., p. 143.
[2]Rogers, Reese F., op. cit., pp. 143-144.

Brown prospect (23)

The Brown prospect owned by C. M. Brown, of Napier, Tenn., is described by Rogers[1] as follows:

"This prospect is located 3 2/5 miles S. 80° E. of Riverside, and 1 1/5 miles S. 11° E. of the junction of Chief Creek with Buffalo River. It is situated on the crests of a high secondary ridge and its spurs, west of Brush Creek. The ridge and its spurs have an elevation of 950 feet, and their crests are nearly 300 feet higher than Buffalo River.

"Surface indications consist largely of a few fragments of loose ore, but chunks and lumps occasionally occur, embedded in the clay soil. Root-wads frequently show shot ore. These exposures sparingly occur over an area of several acres. The surface ore is a light brown siliceous limonite, which analyzed 36.3 per cent. iron; 34.22 per cent. silica; .232 per cent. phosphorus; and .086 per cent. sulphur.

"Water-worn quartz and chert gravel is abundant on the tops of the ridge and its spurs, and if ore exists here in quantity it is evidently covered by these deposits. Surface showings extend over into lands owned by the Davidson, Hicks & Greene Company."

Smith prospect (24)

The Smith prospect owned by Davidson, Hicks & Greene Co., Nashville, Tenn., is described by Rogers[2] as follows:

"This tract is located 3 miles southeast of Riverside, but the outcrop of brown ore here described is located 2/5 of a mile S. 10° W. of the Brown prospect, and on the same secondary ridge as the latter. At this place limonite is exposed around the head of a hollow near the crest of the ridge, and only a few feet west of, and near the crook in the ridge road. The outcrop covers an area of several hundred yards and consists chiefly of boulders and fragments embedded in the soil. A few thousand feet west of this place, several very shallow test pits were found, near the ridge road leading to Allens Creek. Some of these showed a little shot ore in red clay, but the pits are entirely too shallow for test purposes. The only chance of finding much ore on the crest of the ridge is by sinking deep shafts.

"Limonite is reported to outcrop at a number of places between this locality and Perry Hollow, which is 1 2/5 miles southeast of Riverside. The writer did not go over this area in detail, but had seen enough to convince him that the section will warrant systematic prospecting"

Brush Creek prospects

The Brush Creek prospects owned by the Napier Iron Works, Nashville, Tenn., are on the crest of the ridge between Brush Creek and Little Brush Creek. Iron ore associated with water worn chert pebbles occurs along the crest for a distance of 2 to 3 miles. At places the ore appears to be in fair quantity, though sufficient prospecting has not yet been done to determine the extent of the deposits. The separate prospects are described by Rogers[3] as follows:

Brush Creek Bank prospect No. 1 (25)—"This bank is located 4 miles S. 40° E. of Riverside. * * * Boulders and fragments of brown ore are exposed over an area of 48 acres. Within portions of this area the surface is thickly strewn with ore. It has been prospected by ten shallow pits, most of which are 10 to 12 feet long, 4 to 6 feet wide, and 3½ to 4½ feet deep. All but 3 pits show more or less ore, and 2 make

[1]Rogers, Reese F., op. cit., p. 144.
[2]Rogers, Reese F., op. cit., p. 144.
[3]Rogers, Reese F., op. cit., pp. 145-146.

a good showing. The ore occurs in very red clay which contains variable amounts of water-worn gravel and angular chert.

"Rocks outcrop on the east slope of the ridge at approximately 60 feet below the top. Residual ore is exposed 30 feet or more below the crest of the ridge. It is apparent, therefore, that the ore extends to a depth of at least 30 feet."

Brush Creek Bank prospect No. 2 (26)—"This bank is located 3 3/5 miles S. 45° E. of Riverside, and about 3/5 of a mile northeast of Bank No. 1.

"The outcrop consists of boulders and fragments of ore scattered over an area of about 35 acres. Two shallow test pits were found in this area, and these show some ore in very red clay which contains chert fragments."

Brush Creek Bank prospect No. 3 (27)—"This bank is located 4 miles S. 55° E. of Riverside, and ½ mile northeast of Bank No. 2.

"The outcrop consists of boulders and fragments of brown ore scattered in patches over an area of approximately 50 acres, within parts of which the surface is thickly covered.

"The bank has been prospected by 6 shallow pits, 2 of which are blank, remainder showing some ore, principally shot ore. The material in which the ore occurs is chiefly very red clay. The bank should be thoroughly prospected.

"The ore is a dark-brown limonite of good quality. It has a texture varying from compact to cellular, but the compact variety is the most abundant. A sample analyzed 54.08 per cent. iron; 5.79 per cent. silica; 1.916 per cent. phosphorus; and .056 per cent. sulphur."

Allen Creek mines (28)

The Allens Creek mines, also known as the Mannie mines, are on the crests of the ridges just east of the village of Allens Creek which is the terminus of the Centerville Branch of the Nashville, Chattanooga & St. Louis Railway. The mines were opened in 1891 by the Southern Iron Co., of Nashville, which worked them until 1892. They then remained idle until 1895 when the property on which they are located was sold to the Buffalo Iron Co. of Nashville. This company worked the mines from October, 1895 until July, 1902. The property was then acquired by the Bon Air Coal & Iron Company which continued the operation of the mines until April, 1913. In January, 1916 mining was resumed by receivers of the Bon Air Coal & Iron Company and was continued by them until June 15, 1917, when they sold the property to the Bon Air Coal & Iron Corporation, which was operating the mines at the time of last visit (April, 1920).

Two Furnaces known as Mannie Furnace No. 1 and Mannie Furnace No. 2 were erected in 1892 (see Plate IV, A) and have been operated since then whenever the mines have been operated.

The production of iron ore before October 1, 1895, was probably 75,000 tons and the production from that date until December 31, 1920, was 1,255,693 tons. The total production is therefore 1,330,693 tons.

The workings are open cuts which comprise an area of about 40 acres. They are as much as 60 or 65 feet deep and will average 50 feet deep.

The iron ores occur in the residual chert and clay of the St. Louis limestone, and at places in pockets and lenses of sand and gravel that

are present in or above the clay. The total depth of these surficial materials is not known, but it probably everywhere exceeds 60 or 65 feet, the maximum depth of the workings. No rock ledges, either limestone or chert, have been found in the workings, though at places there are layers of chert 3 to 6 inches thick that are fractured and bent.

The bending and fracturing of the chert layers was caused by slumping during the removal of the limestone through solution. Most of the chert fragments, however, are irregularly distributed through the clay. A great deal of the chert is hard; the rest is soft and when struck by a hammer becomes a fine powder resembling tripoli.

Over much of the ore-bearing area the soil and subsoil have been leached to a light-yellowish color to a depth of 1 to 2 feet; a bright red loam 1 to 4 feet thick occurs beneath this; and below this loam the clays are usually yellow but at places are red and at others are white.

The pockets and lenses of gravel and sand vary greatly in size and shape; they are numerous; and some of them are found below layers of chert. (See Figure 3). The sand contains considerable mica in small flakes. The pebbles in the pockets of gravel are hard, subangular to well-rounded, usually ½ to 2 inches in diameter, though some are as much as 5 inches in diameter. They are mostly chert but are partly quartz. A few fragments of chert in the pockets are angular and appear as if they had not been waterworn at all. The chert pebbles, as is indicated by fossils in them, were derived from beds in the St. Louis limestone. They have, however, been waterworn except for the few angular fragments that have just been mentioned and they were apparently deposited by streams before the removal of the calcium carbonate of the limestone. The source of the quartz pebbles is unknown. The streams deposited not only gravel but sand and probably some clay. That the stream-laid materials were deposited before the removal of the limestone is shown by the occurrence of pockets of sand and gravel below clay that contains nearly horizontal layers of fractured chert. This means that some of the materials were deposited in limestone sinks or other surface irregularities.

The ore occurs mostly in irregular masses of large and small size. Many of the masses are solid but others are reticulated, being composed of a network of veins. The larger masses occur here and there and are generally 10 feet or more below the surface but become fewer below a depth of 30 feet. The ore at and near the surface consists of small fragments, varying in size from shotlike pieces to those 2 to 3 inches in diameter. Experience in mining is said to show that most of the ore is in the centers of the ridges. Parts of the ore contain much quartz sand and parts inclose clay and fragments and pebbles of chert so that the silica content of such parts is high. The top fragmentary ore is better in quality than the lower more massive ores, the latter being subject to high percentages of silica.

The ratio of washed ore to ore-bearing material has for several years averaged 1 ton of washed ore for every 4 cubic yards of loose ore-bearing material.

The iron content of the washed ore as determined by the chemist of the company ranges from 43 to 50 per cent and averages about 47 per cent, the per cent of alumina (Al_2O_3) ranges from 2.5 to 3.5, that of silica (SiO_2) ranges from 15 to 18, that of phosphorus (P) from .8 to 1.25 and that of manganese (Mn) from .25 to .30.

The accompanying analyses represent the composition of samples of iron ore that were collected by N. F. Drake.

Analyses of iron ore from the Allens Creek mines.

(Paul C. Bowers, analyst).

Iron (Fe)	56.89	53.86	51.01
Phosphorus (P)	1.372	1.39	.64
Sulphur (S)	.007	.006	.017
Silica (SiO_2)	4.21	7.14	11.18

Although the deposit at this locality has not been thoroughly prospected beyond the cuts the total ore-bearing area is considerable. It is reported to be 500 acres and tonnage estimates that have been made are reported to vary from 3,000,000 to 9,000,000.

Three steam shovels were being used at the time of last visit to mine the ore. From the mine the ore is conveyed over tram roads to the washing plant, and for this purpose six locomotives are used. The plant has a daily capacity of 400 tons of washed ore and is equipped with a double steel log-washer of the McClanahan-Stone type, three sets of jigs, screens, and a picking belt. The ore that occurs in particles less than 1/4 inch in diameter is not recovered. Water for the plant is piped from Buffalo River near Riverside, a distance of about 2 miles.

The clay horses in the ore deposit are avoided in mining as they generally contain very little ore and the pebbly parts of the deposit are avoided as much as possible because the jigs in the washing plant are unable to separate them entirely from the ore.

Charcoal was used in the furnaces from 1892 until 1900 when the experiment was tried of using both charcoal and coke, but this was not successful and the use of coke alone was begun.

For many years limestone flux was obtained from the Laurel and Lego limestones in several quarries near Riverside and between this place and the village of Allens Creek, but owing to impurities in these limestones their use was discontinued 10 years or more ago and limestone has been shipped in recent years from Lyles, Tenn. The accompanying analyses of a sample collected by the writer from a quarry in the Laurel limestone one-fourth mile south of Riverside shows that the chief impurities are silica, alumina, and ferric oxide.

Analysis of Laurel limestone from quarry ¼ mile south of Riverside

(R. K. Bailey, of U. S. Geological Survey, analyst).

Silica (SiO_2)	1.32
Alumina and ferric oxide (R_2O_3)	.92
Lime (CaO)	49.64
Magnesia (MgO)	4.80
Carbon dioxide (CO_2)	43.90

The pig iron that is produced by the furnaces contains 1.75 to 2.75 per cent of phosphorus and .19 to .77 per cent of manganese.

Percy mine (29)

The Percy mine is on the crests of a ridge and its spurs almost 1 mile southeast of Riverside. The ridge is between 950 and 1,000 feet above sea level and between 250 and 300 feet above Allens Creek which runs north past the west base of the ridge.

The property was purchased by the Warner Iron Company on March 28, 1899. This company opened the mine in that year and operated it and a washing plant more or less continuously until January 27, 1919, when the mine and the equipment were sold to the Bon Air Coal & Iron Corporation. This corporation was operating the mine and washing plant at the time of last visit (April, 1920). The production by the Warner Iron Co. was 404,821 tons of iron ore which was shipped to Cumberland Furnace in Dickson County, Tenn. The production by the Bon Air Coal & Iron Corporation from January 27, 1919 to December 31, 1920 was 64,660 tons of iron ore which has been shipped to the Cumberland and Goodrich furnaces. The total production before December 31, 1920, was therefore 469,481 tons.

The mine consists of a number of cuts located at different places on the property. (See Plate IV, B). Their aggregate area is about 20 acres and their maximum depth between 60 and 70 feet.

The iron ore is irregularly distributed through loose material composed largely of red clay but composed partly of chert fragments, sand, and gravel, and neither the ore nor this material has been passed through in the workings. The clay and chert fragments, as at other mines in the Waynesboro quadrangle, have been derived from the St. Louis limestone whereas the sand and gravel which occur in lenses and pockets are probably stream deposits of Upper Cretaceous age. The iron ore is generally free from quartz sand. It reaches the surface at some places but at others good pockets of high-grade ore are concealed by as much as 15 feet or more of barren material. The pebbles in some of the gravel lenses are cemented together by iron oxide, forming a hard conglomerate and large masses of this conglomerate are avoided as much as possible in mining.

The ratio of washed ore to ore-bearing material has for several years averaged 1 ton of washed ore for every 3 cubic yards of loose ore-bearing material.

In composition the iron ore is very much the same as that from the Allens Creek mines, except that it contains more phosphorus than that from the Allens Creek mines. The accompanying analyses represent the composition of samples of ore that were collected by N. F. Drake.

Analyses of iron ore from the Percy mine

(Paul C. Bowers, analyst.)

Iron (Fe)	51.01	49.85
Phosphorus (P)	1.247	1.417
Sulphur (S)	.002	.004
Silica (SiO_2)	6.27	12.52

Sufficient prospecting has not been done to determine the total area of ore-bearing material nor to determine the full thickness of the deposit.

The Warner Iron Company operated a washing plant equipped with a double steel log washer of the Stone-McClanahan type. It used a steam shovel for mining the ore and a tram line for hauling the ore to the tipple. (See Plate IV, B.)

The Bon Air Coal & Iron Corporation is operating the Percy mine with two steam shovels and is using three locomotives to convey the ore-bearing material over tram roads to the washing plant which is equipped with screens, a crusher, picking belts and three sets of jigs. On account of the comparatively small amount of clay in the ore-bearing material the use of a log washer has been discontinued. Water for the washing plant is piped from Buffalo River near Riverside, a distance of about 1 mile.

Churchwell prospects (30)

Two prospects which are on the Churchwell property are east of Fortyeight Creek and between Duggar Branch to the north and Little Fortyeight Creek to the south. This property has an area of 167½ acres and is owned by Clarence Reese, William Millsaps and the Boyd brothers. Some of the prospecting was done by the present owners in 1918 but some of it was done earlier by the Middle Tennessee Iron Co.

One of the prospects is on an iron-ore tract of 3 or 4 acres on the crest of a southwestward-trending ridge. The tract has been prospected by means of numerous pits as much as 26 feet deep. All of the pits, except three, show brown iron ore in the form of shot ore and lump ore in clay in which there is at places considerable chert. Three of the pits are blank. The ore-bearing clay extends from the surface to different depths but the average depth over the tract is apparently between 6 and 8 feet. The chert and clay on this tract have been derived from the lower part of the St. Louis limestone.

The second prospect is on the crest and west slope of a spur ridge that extends westward from the north side of the ridge on which the first tract occurs. The ore-bearing tract on which the prospect occurs comprises several acres and has been prospected by means of 12 pits which range in depth from a few feet to 41 feet. Three of them failed to show brown iron ore; the others however show it in considerable quantity. The ore occurs as the varieties known as "shot," "lump," and "bomb shell" ore and much of it is in red clay but some is in chert that has been derived from the lower part of the St. Louis limestone. It was found at places on the crest and at places as far as 50 feet below the crest. The deepest pit, which is 41 feet deep, is on the crest; it revealed ore in St. Louis chert from the surface to a depth of 30 feet, and below this it penetrated the yellow Fort Payne chert which contains no ore. The next deepest pit, with a depth of 32 feet, which is also on the crest, passed through 20 feet of chert and gravel and then penetrated 12 feet of ore-bearing chert.

The two ore-bearing tracts here described contain an ore of good quality and apparently contain it in minable quantity. Water for its concentration may be obtained from Fortyeight Creek which runs past the west base of the ridge on which the last-described tract is located.

Robinett prospects (31)

The Robinett prospects are on the Robinett property which comprises 1,250 acres on and near the lower course of Little Fortyeight Creek. Prospecting has been done on three ore-bearing tracts and they are here described as prospects Nos. 1, 2, and 3. The mineral right of the property is owned by Clarence Reese, William Millsaps, and the Boyd brothers. The prospecting was done mostly in 1918 by G. W. Boyd and William Millsaps; the other prospecting was done many years ago by the Middle Tennessee Iron Co.

Prospect No. 1 is between Fortyeight and Little Fortyeight creeks, and is on the crest of a short spur ridge that trends northeastward from the main ridge between these streams. Thirty-eight pits which include practically all of the openings were examined. They range in depth from a few feet to 30 feet and occur on the crest and a few feet below it over an area of probably 40 acres. They all reveal shot ore and some lump ore in red clay in which there is only a small quantity of chert. The ratio of ore to the ore-bearing clay appears to be 3 or 4 parts (by weight) of ore-bearing clay to 1 part of ore. The shallow pits do not pass through the clay but the deeper ones show it to be about 20 feet thick and to be underlain by chert. The ore is brown iron oxide, is compact and hard and is free from sand. The deposit apparently contains ore in minable quantity. It is accessible to a sufficient water supply for washing the ore, being half a mile southwest of Little Fortyeight Creek and the same distance east of Fortyeight Creek.

A short spur ridge just southeast of the ridge on which the above-described tract is located is said by G. W. Boyd to show ore on the surface on the crest but thus far, it has not been prospected.

Prospect No. 2 is on the crest of a northwestward-trending ridge a short distance west of prospect No. 1. Three pits were examined. One of these, 3 or 4 feet deep in clay, revealed no ore; another, 18 feet deep in clay, revealed 13 feet of ore-bearing clay; and the other, 33 feet deep, revealed 30 feet of ore-bearing clay. Surface showings of ore are said to occur on the crest for a considerable distance northwest of the pits but these were not examined. Further prospecting will probably prove the presence of a workable ore body of considerable size.

Prospect No. 3 is on the crest of a narrow east-west ridge three-fourths of a mile east of Fortyeight Creek and half a mile north of the mouth of Blowing Spring Branch. One pit, 12 to 15 feet deep, revealed brown iron ore from the surface to the bottom. This pit and the presence of such ore on the surface indicate that the ore-bearing area is perhaps 4 or 5 acres in extent. The ore is compact and hard and includes both shot ore and lump ore. It occurs in clay and chert which have been derived from the lowermost beds of the St. Louis limestone; the Fort Payne chert, the next lowest formation, is exposed on the hillslopes just below the outcrops of the deposit.

Wayne Furnace mines

Location, history, and production

A number of iron-ore deposits, owned by the Tennessee Charcoal Iron Company, are near Wayne Furnace which is on Furnace Branch 5 miles east by north of Waynesboro. For many years before and after the Civil War they produced iron ore which was used in the above named furnace. The quantity of ore thus used is estimated to have been 145,000 tons.

Wayne Furnace was one of the most important of the early furnaces of west-central Tennessee. Many interesting facts regarding the furnace were published in 1874 by J. B. Killebrew and J. M. Safford,[1] after whom the following is quoted:

"Thirty-five years ago, two furnaces were erected upon the same ground where Wayne Furnace now stands. One of them was discontinued and the other was kept in blast for many years. Six years ago, the Gaylord Iron & Pipe Company, of Kentucky, bought the property for $40,000, inclusive of 21,000 acres of land, and set to work to repair it. They introduced the hot blast, erected new stacks, and began operations on a scale much more extensive than ever before. The capacity of the furnace was increased to 24 tons per day, but it rarely makes above 18. The iron manufactured is cold short, and is unfit for boiler plate, car wheels, or wrought iron. It is mostly consumed in the foundry owned by the same company in making iron pipe. One hundred and fifty bushels of charcoal are consumed in making one ton of pig iron.

[1]Killebrew, J. B., and Safford, J. M., Introduction to the resources of Tennessee, pp. 976-977, Nashville, Tenn., 1874.

The estimated cost of charcoal at present at 6 cents per bushel. The cost of green ore delivered at the furnace, $2 per ton, of which 2½ tons are used to 1 ton of iron; cost of limestone per ton of iron, 50 cents; labor and salaries, $6.44; incidentals, such as sand, hearth, interest, etc., $1.33; making present cost of a ton of iron $21.97. It costs $5 per ton to get to Clifton, on the Tennessee River, and $3.62 from that point to Cincinnati, making its present (January, 1874) cost in Cincinnati $29.59. It must be remembered, however, that much of this labor is paid for in goods, upon which a profit of from 30 to 50 per cent is made.

"About 200 hands are kept in constant employment, and nearly all the work is done by contract. Sixty cents per cord is paid for cutting wood; $2 per ton for digging and delivering ore; daily laborers, $1.20 per day; skilled laborers, $1.60. The furnace force consumed annually 20,000 bushels of corn, 30,000 pounds of bacon, 600 barrels of flour, 1,200 bushels of corn meal, and 360 tons of hay. It may be stated as a significant fact that all the hay and most of the bacon are brought from Indiana and Kentucky. This furnace furnishes the best market in the county.

"The height of the stack of Wayne Furnace is 42 feet; width across boshes, 11 feet; hot blast, the blast being heated by the waste heat from the trundle head. It is driven in through two tuyeres. Capacity of furnace, 5,800 tons annually."

The following information relating to the history of the furnace was given to the late Dr. A. H. Purdue by A. E. Boyd, of West Point, Tenn.[1]

"The furnace was built by the Fargisons in 1833. The air blast was furnished by water power. From 2½ to 3 tons of iron per day were made and most of this was used in the manufacture of hollowware, such as kettles and pots. After having operated the furnace for several years the Fargisons sold to a Mr. Warfield, who ran it on much the same plan as the Fargisons. He remained in the business for several years, but met with little success in making pig iron. Eventually, he sold out to a Mr. Walker, of Nashville, Tenn., who operated with slave labor and was successful in the business. A short time previous to the Civil War Mr. Walker sold to the Pointer Brothers, who increased the capacity to 6 or 7 tons a day and operated till 1864. These men found a market for their iron in Louisville and Cincinnati.

"In 1865, the Pointer Brothers traded the property to B. B. Gaylord, of Portsmouth, Ohio. By this deal the Gaylord Iron & Pipe Company was organized and placed under the management of Col. G. W. Boyd, of Ironton, O., Colonel Boyd took charge of the furnace in 1868, and expended $20,000 for equipment, increasing the capacity to 26 tons a day. The largest year's run made under Colonel Boyd's management was 6,000 tons. This brought $50.00 a ton on the bank of the Tennessee River, at Clifton. The furnace was run under this management until 1875, at which time it was closed, and has not been operated since. Subsequent to its closing the property has changed hands several times."

The following additional information concerning the operation of the furnace by Col. Boyd was furnished the present writer by A. E. Boyd:

The crude ore was hauled in wagons from the different openings to the furnace and for this purpose 150 head of horses and mules were required. The charcoal was hauled in 6 wagons with a capacity of 200 bushels each and each wagon was drawn by 6 mules or 8 oxen. The pig iron was hauled in two to six-horse wagons to Clifton via Waynesboro, a distance of 22 miles, and corn, hay, and other provisions were hauled from Clifton on the return trip. For this purpose about 150 horses and mules were used. Two days were required for the round trip and the

[1]Purdue, A. H., The iron industry of Lawrence and Wayne counties: The Resources of Tennessee, vol. 2, No. 10, p. 374, Oct., 1912.

cost of the trip was $5 per ton of pig iron and $3 per ton of corn, hay, and other provisions.

Charcoal for the furnace was made by burning the oaks and other hardwoods that forest the surrounding region. Limestone for flux was obtained from the Bob Limestone on Fortyeight Creek half a mile north of the mouth of Furnace Branch, and 1½ miles northeast of the furnace. The limestone that is exposed at the old quarries is described on page 127.

The tracts under discussion were visited last in April, 1920, and since then the Tennessee Charcoal Iron Co. has planned to mine iron ore from one or more of the tracts and to ship it to Anna Furnace at Collinwood for the manufacture of charcoal pig iron. In accordance with this plan, it has begun the construction of a railroad 16 miles long running from Collinwood to Wayne Furnace and has done further prospecting on some of the ore-bearing tracts.

Geology

Chert and clay, that have been derived from the lower part of the St. Louis limestone, cap the ridges on which the ore-bearing tracts occur and are probably between 50 and 100 feet thick. No undecomposed limestone is exposed at any place on the surface and none has been encountered in the openings. None of it may be present in the ridges on which the mines occur and if so its residual chert and clay rest directly upon the Fort Payne chert which is exposed on the lower slopes of the ridges and along the streams. The Fort Payne, however, is generally concealed by debris that is derived mostly from the St. Louis limestone. Waterworn pebbles are mixed with the clay and chert fragments near the surface at many places on and near the crests of the ridges. The pebbles are well-rounded and are mostly chert, though some of them are quartz.

The iron ore occurs as branching or reticulated veins, both wide and narrow, in the clay, chert and gravel and the veins include these materials at places. Most of the chert thus included in the ore is very soft and crumbles to a fine powder when it is struck with a hammer. The ore is hard, is generally free from sand, and is chiefly a brown oxide of iron but a small amount of it is a red oxide. The accompanying analyses represent the composition of samples of iron ore from the Wayne Furnace mines.

Analyses of iron ore from the Wayne Furnace mines

	1	2	3	4	5
Iron (Fe)	52.28	50.86	52.91	53.55	54.52
Manganese (Mn)		1.49			
Phosphorus (P)	.88	.982	1.561	.744	.874
Sulphur (S)			.015	.021	.01
Silica (SiO_2)	9.41	11.25	7.30	11.90	9.11

1. Sample composed of 462 pieces, taken from 5 different shafts. Analysis furnished by W. C. Collin. Wuth & Safford, analysts.

2. Sample composed of 9 pieces. Analysis furnished by W. W. Collin, Pittsburg Testing Laboratory, analyst.

3,.4, and 5. Samples collected by N. F. Drake. Paul C. Bowers, analyst.

Mining and preparation of ore

The ore for Wayne Furnace was mined by hand in open cuts and short drifts at numerous places. After it was hand picked to eliminate, so far as possible, the clay and chert and was dry screened so as to save the fragments half an inch or more in diameter, it was hauled in wagons to the furnace. The miners were not paid a daily wage but were paid $1.75 per ton of ore delivered at the furnace. This policy of payment led them to work wherever they could obtain the greatest possible amount of ore per day, and as a result no systematic mining was done.

After the ore had been hauled to the furnace it was spread in layers on ricks of wood which were then set on fire and burned. The object in doing this was to free the ore, so far as possible, from the clay and chert that had not been removed by handpicking and dry screening, but in addition to this the ore was thus dried and even chemically combined water was driven off. The loss of water is shown by the fact that all of the ore at one of these old rick sites, which was examined by the writer, had been changed by being burned from a brown oxide to a red oxide of iron. These ricks were several feet wide, 100 feet long and as much as 15 to 20 feet high. Their foundation was a platform of wood, 20 inches high, with a space of 8 to 10 inches next to the ground. On this there was spread a layer of iron ore 5 or 6 inches thick and on this layer of ore there was spread a layer of fine charcoal 5 or 6 inches thick. The alternate placing of the layers of charcoal and ore was continued until the rick reached the height that is indicated above. The larger fragments of ore were placed on the edge of the ricks and the fine ore near their middle.

Future mining will be done for the most part in open cuts but the great thickness of the overburden at some places will probably necessitate underground mining at such places. To free the ore from the clay and chert would require a washing plant equipped with a crusher, logs, and jigs.

Materials for construction of Wayne Furnace

Fire brick for the furnace were transported up Tennessee via Clifton, but the common brick were made from surficial loam that underlies the stream flat along Furnace Branch east of the furnace.

A mass of iron that was removed from the bottom of the furnace was observed on the bank of Furnace Branch and the fragments of sandstone that adhere to its lower side show that the hearth of the furnace was built of sandstone. The character of the sandstone indicates that it was obtained from the Hardin sandstone. The nearest exposures

of this sandstone and probably the ones from which the sandstone for the hearth were obtained are along Fortyeight Creek north of the mouth of Louse Hollow.

East Furnace Ridge mine (32)

The East Furnace Ridge is on the crest of a ridge by this name which extends southward from the ruins of Wayne Furnace. These ruins are at the base of the ridge and are about 750 feet above sea level, and the ridge at places attains an elevation of about 920 feet above sea level, or about 170 feet above the ruins.

The openings which consist of 60 or more pits, cuts, and shafts and short tunnels have been made here and there over an area of more then 30 acres on and near the crest of the ridge, though a few of them are as low as 80 feet below the crest. (See Figure 4). They range in depth from a few feet to 48 feet, but more than half of them exceed 20 feet in depth. The cuts and tunnels are old openings from which iron ore was removed for use in Wayne Furnace but most of the openings are test pits which were made in recent years by W. C. Cronemeyer. The ore lies in a bed-like body and has been proved by the openings to occur over an area of 30 acres. The ore body is not entirely continuous or regular over all this area, but most of the openings reached iron ore; only a few of the deeper ones failed to find it and some of the shallower ones were obviously not sunk deep enough to strike it. The ore body as revealed in the openings varies in thickness from a few inches to about 30 feet and will probably average not less than 10 feet. The ore is massive and hard and is fairly free from impurities, except that at places it contains some clay and angular chert. The mine run ore will probably yield one ton of marketable ore to one ton of waste. The overburden of chert, clay, and gravel varies in thickness from nothing to about 30 feet.

West Furnace Ridge mine (33)

The West Furnace Ridge mine is on a ridge by this name which is south of Furnace Branch and west of East Furnace Ridge. About 20 openings consisting of cuts and shafts have been made on and near the crest of the ridge near its north end. (See Figure 4). The shafts vary in depth from 22 to 50 feet but none of the cuts exceed 12 feet in depth. A few of the openings were made many years ago during the operation of Wayne Furnace, but most of them were made in recent years by W. C. Cronemeyer. About half of the openings revealed little or no ore, but the rest revealed from a few feet to more than 30 feet of ore-bearing chert and clay which will yield at least one ton of marketable ore to one ton of waste. Although this deposit has not been fully prospected, sufficient work has been done to show that the ore is present in workable quantity

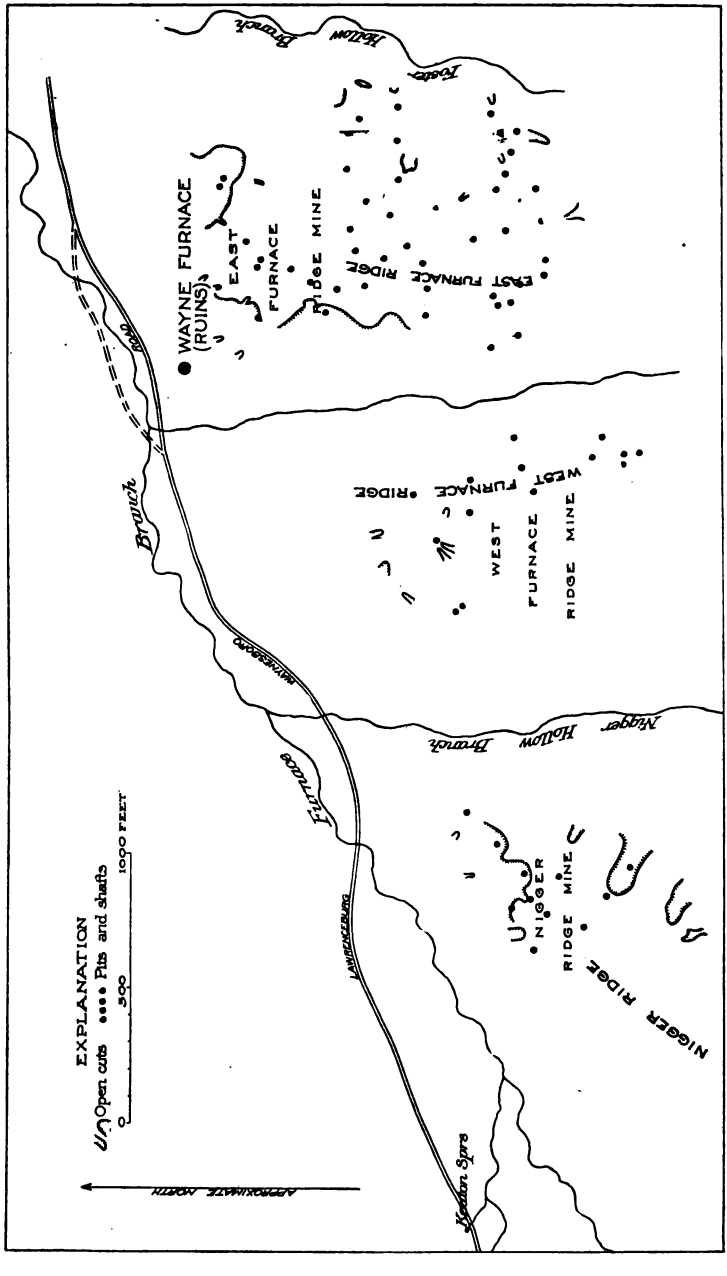


FIGURE 4.—Map showing the openings at the East Furnace Ridge, West Furnace Ridge, and Nigger Ridge mines at Wayne Furnace. Drawn from map by W. C. Cronemeyer.

Nigger Ridge mine (34)

The Nigger Ridge mine is on Nigger Ridge which is west of West Furnace Ridge and lies between Lathen Hollow to the west and Nigger Hollow to the east. Between 15 and 20 openings have been made over an area of about 10 acres at and near its northeast end. (See Figure 4). They include old open cuts, an old tunnel, and a number of recently-made shafts as much as 38 feet deep. They have been made at different elevations from the crest of the ridge down to about 75 feet below the crest. Probably more than half of them revealed iron ore in clay and chert. Although the thickness and character of the ore-bearing material vary considerably it will probably average more than 10 feet thick over the prospected area and probably yield marketable ore in the ratio of one part of marketable ore to one part of waste. The overburden in the openings that revealed ore reaches a thickness of perhaps 20 feet, though at most places it is much thinner or is absent.

Iron ore was mined at this locality while Wayne Furnace was in operation.

Foster Hollow prospect (35)

The Foster Hollow prospect is on the northwest point of the hill that is east of the mouth of Foster Hollow. This hollow is just east of East Furnace Ridge and is the first hollow that is found in going east from Wayne Furnace.

Four shallow pits have been made at an elevation of about 75 feet above the base of the hill. These were dug in yellow clay in which there are chert fragments. One of them revealed considerable iron ore of good quality but the other three revealed very little of it.

Lee Ridge mines (36)

The Lee Ridge mines are on the crest of Lee Ridge which lies between Louse Hollow to the north and Furnace Branch to the south. Besides the main ridge which trends east-northeast there are many short spurs on either side. Iron ore was mined at numerous places on this ridge and its spurs many years ago during the operation of Wayne Furnace and it supplied a part of the iron ore that was used in that furnace. Some prospect pits have been made in recent years.

About 70 openings which include practically all of the openings on the ridge were examined by the writer. These consist of cuts as much as 150 feet long, 100 feet wide, and 15 feet deep, pits 10 feet or less deep, and a few short drifts. They have been made at numerous places on the main ridge and its spurs through an east-west distance of half a mile and have been made not only on the crest but also on the slopes as much as 50 feet below the crest.

The materials revealed in surface outcrops and in the openings are iron ore, red and yellow clay, pebbles of chert, and fragments and layers of chert. Of the materials associated with the iron ore the clay is in smallest quantity and the pebbles occur only at and near the surface.

The iron ore occurs as fragments at and near the surface and as irregular branching veins of large and small size in the deeper parts of the openings; it was found in practically all of the openings. It is hard and compact and is free from sand but much of it contains fragments of chert. At many places it reaches the surface but at others especially on the crest of the ridge it is overlain by 10 feet or more of overburden which consists of chert fragments and pebbles, though the average thickness of the overburden will probably not exceed a few feet. The ore appears to occur in minable quantity over an area of 60 acres or more but its depth and full areal extent should be determined by systematic prospecting before any mining is begun.

Broach mine (37)

The Broach mine is on the south point of a hill on the northwest side of Furnace Branch and is opposite Nigger Ridge, this ridge being on the southeast side of the branch. It was worked during the operation of Wayne Furnace and yielded a small quantity of iron ore which was used in this furnace.

The workings consist of two cuts about 60 feet above Furnace Branch and two or more very small pits. One cut is 12 feet long, 8 feet wide and was 6 feet or more deep before it caved in, and the other which is 10 feet east of the first is 30 feet square and has a face with a height of about 12 feet at the north end. The cuts were badly caved at the time of visit (April, 1920) so that the character of the ore was determined for the most part from the material on the old dumps. The ore on the dumps consists of large and small fragments of hard iron oxide and some of the fragments especially the larger ones contain chert fragments.

Shallow pits that are east of the cuts reveal only a small quantity of iron oxide but a pit and an outcrop which are 75 feet northwest of the cuts reveal massive ore which contains many chert fragments and pebbles.

Keaton Springs mine (38)

The Keaton Springs mine is on the southeast points of the two spurs that are west of the Broach mine. Keaton Springs issue at the south base of the westernmost spur and at the north side of the Waynesboro-Lawrenceburg Road. Several shallow pits have been made within an area 100 feet square on the southeast point of the westernmost spur at an elevation of 80 feet above Furnace Branch. Massive ore in which there are chert fragments was obtained from the pits and after handpicking and dry screening was hauled to Wayne Furnace where it was used. The

small pits on the other spur reveal ore of the same character. Further prospecting will be required to determine whether or not there is enough iron ore at this bank and the Broach mines to be mined under present conditions.

Perigo mine (39)

The Perigo mine is on a hill on the southeast side of Louse Hollow and three-fourths of a mile northwest of Wayne Furnace. It was worked many years ago and furnished some of the ore that was used in that furnace.

The openings consist of three cuts. The largest of these is on the northwest slope of the hill and is 35 feet below the crest. It is 30 feet wide and 50 feet long; and before it caved it had a face 15 feet or more high. It reveals a large amount of ore in irregular veins and masses in clay in which there are many chert fragments and some chert pebbles. As would be expected much of it contains fragments and pebbles of chert. The other cuts which are 10 to 15 feet deep are on the east slope of the hill and they show considerable iron ore in clay which is comparatively free from chert.

Spurs north of Louse Hollow

Iron ore is reported to show on the surface on the south points of the short ridge spurs which occur on the north side of Louse Hollow from its head to its mouth, a distance of about 1½ miles. There are about twelve of these spurs. No prospecting has been done on them, except at one place where a small amount of ore was mined for use in Wayne Furnace. None of the spurs were visited by the writer.

Irontop mine (40)

The Irontop mine is 6 miles northeast of Waynesboro and is on the crest of the ridge that is followed by the wagon road from Waynesboro to Allens Creek. It was worked on a small scale many years ago and the iron ore from it was used in Wayne Furnace.

Two recently made pits on the crest, one 15 feet deep and the other 20 to 25 feet deep, reveal chert and clay and a considerable amount of iron oxide. Several old pits all of small size which produced ore for Wayne Furnace are on the west and north slopes of the ridge. Shot ore and lump ore occur on the surface near the openings and along the wagon road for a distance of about one-fourth mile. The prospecting that has been done thus far has not been sufficient to determine the thickness and extent of the ore body.

Iron ore is said to occur on the surface on the northwest points of all of the several short spurs between the Irontop mine and the head of Bowstring Branch. This branch heads about 1¼ miles southwest of

the mine under discussion and flows northeastward into Fortyeight Creek. Thus far none of these points have been prospected.

Murphy mine (41)

The Murphy mine is on the east point of a ridge just west of Fortyeight Creek, 1¾ miles southeast of Wayne Furnace and 6 miles east of Waynesboro. It was worked many years ago and the iron ore from it was hauled to Wayne Furnace. The openings consist of three shallow badly caved trenches from 60 to 80 feet long and four pits as much as 20 feet deep. The trenches and one of the pits revealed much iron ore in chert and clay on the east slope of the ridge but the other three pits that were dug on and near the crest failed to discover ore in paying quantities in the chert and gravel which they penetrated. The failure to find ore on and near the crest apparently indicates that the ore-bearing area is confined to the east end of the ridge. The ore-bearing area probably does not exceed a few acres in extent. The ore as revealed on the old dumps and in the openings is brown iron oxide which is hard and is free from sand.

Crews mine (42)

The Crews mine is half a mile west of Fortyeight Creek and 1½ miles southeast of Wayne Furnace. It is about one-fourth mile west of the Murphy mine, and is on the north slope and near the base of the ridge on which the Murphy mine occurs. The openings consist of two badly caved cuts which supplied iron ore for Wayne Furnace. One of these is 10 to 15 feet wide and 70 feet long and was 15 feet or more deep before it caved. The other which is just west of the first is 50 to 60 feet wide and 60 feet long and was originally 25 feet or more deep. At the time of visit (April, 1920) the ore was not visible in the cuts owing to their having caved in. The old dumps, however, show that the ore is a hard brown iron oxide which is free from sand. The materials with which it is associated are clay, chert, and pebbles.

A very small pit has been dug on the north side of the wet weather branch which runs east past the cuts. It reveals brown iron oxide associated with chert.

Sapling mine (43)

The Sapling mine is on a ridge about one-fourth mile west of Fortyeight Creek and 1½ miles southeast of Wayne Furnace. It is one-fourth mile northwest of the Murphy mine and the same distance northeast of the Crews mine. The openings consist of 15 to 20 pits and cuts which were dug many years ago over an area of 3 or 4 acres on the crest and south slope of the ridge. Although they were badly caved at the time of visit their depth does not appear to have exceeded 10 feet. Most of them revealed brown iron oxide of good quality in clay in which there

is a comparatively small amount of chert. They produced some ore for Wayne Furnace and the size and number of the openings suggest that they produced more ore than the near-by Murphy and Crews mines. The occurrence of a blank pit higher on the ridge than the openings and just west of them suggests that the iron-ore deposit is confined to the east end of the ridge, but systematic prospecting may reveal an ore body that can be worked with a steam shovel. There appears to be little or no overburden above the ore-bearing clay.

West mine (44)

The West mine is on the east end of a ridge one-fourth mile west of Fortyeight Creek and 1¼ miles southeast of Wayne Furnace. The main opening is a cut, 100 feet square and 15 feet or more deep, on the north slope of the ridge. It was made in brown clay in which there are chert fragments and pebbles and considerable brown iron ore. Ore from this cut was hauled to Wayne Furnace. Another cut, 30 feet long, 12 feet wide, and 10 feet or more deep, also supplied some ore for that furnace. A few pits as much as 25 feet deep have been made on the east end of the ridge and some of them revealed a considerable quantity of iron ore. Although ore has been mined by crude hand methods at this bank, much additional prospecting will be required to determine whether or not the ore body is large enough to be mined profitably with a steam shovel or by other methods.

Lee Hollow mines (45)

An ore-bearing tract is just south of Lee Hollow which is a southeastward-trending hollow followed by the Waynesboro-Lawrenceburg Road just east of the Fortyeight Creek. Iron ore was mined by hand at different places on this tract many years ago and was hauled in wagons to Wayne Furnace. The next work which consisted entirely of prospecting was begun in 1918 by the Tennessee Valley Iron & Railroad Co., which has since been succeeded by the Tennessee Charcoal Iron Co., and up to the time of visit (April, 1920) 50 new pits had been dug on the tract.

The old workings are pits and drifts. The old and new pits range in depth from a few feet to 42 feet and the drifts are as much as 50 feet long. They were dug over an area of between 100 and 150 acres on the ridge south of Lee Hollow and on two adjoining ridges which are spurs that extend southwestward from the first-mentioned ridge. They were dug not only on the crests but on the slopes as far as 50 feet below the crests.

A bed of gravel composed of well-rounded chert pebbles and ranging from a few feet to 10 feet or more thick caps the ridges at most places. It rests upon clay and chert which have been derived from the Weathering of the St. Louis limestone. The chert is gray and ranges in hardnes

from soft to hard and predominates over the clay at most places. It and the clay are revealed on the hill slopes but also occur on the crests at places.

The ore is brown iron oxide and occurs in large irregular masses, brancing veins, and bomb shells (see Plate IX) in the clay and chert, but at places it occurs in the overlying gravel as a cementing material. It is by no means uniformly distributed through the clay and chert and for this reason much nearly barren chert and clay occur in the ore-bearing zone and probably could not be mined successfully. Furthermore the gravel including the ferruginous gravel conglomerate is waste and is therefore overburden. The minable ore at places is 25 feet or more thick. It is mostly massive, is compact and hard, and is generally free from sand but contains much chert and clay. (See Plates VII, B and VIII).

The openings show the ore body to extend about 50 feet below the crests of the ridges and although they have been made over an area of between 100 and 150 acres, a small proportion of them reveal no ore so that the ore body or bodies that appear to be of minable size would probably comprise considerably less than 100 acres.

Mining can probably be carried on to a great extent in open cuts but the great thickness of the overburden at most places on the crests of the ridges may make underground mining necessary there.

Tract north of Lee Hollow

A reported occurrence of iron ore is on the part of the property of the Tennessee Charcoal Iron Co. that lies between Lee Hollow and the Robinett property. The ore is said to show on the surface on the crests of the ridges. Thus far no prospecting has been done here.

Nutt prospect (46)

The Nutt prospect is on the crest of a ridge 6 miles northeast of Waynesboro and is on the property which is owned by Henry Nutt. This property joins the east side of the tract on which the Irontop mine is located. Iron ore in the form of shot ore and lump ore was observed on the surface, in one or two old pits, and in three mats for a distance of about 100 yards east of the Irontop tract.

Buchanan prospects (47)

The Buchanan prospects which are on the property of Dr. C. Buchanan of Waynesboro, are on the headwaters of Fortyeight Creek, 7 miles east of Waynesboro. This property comprises an area of 1,107 acres and its west side joins the property of the Tennessee Charcoal Iron Co. A small amount of prospecting was done a few years ago by G. W. Boyd and a like amount was done many years ago. Ten pits

ranging in depth from a few feet to 15 feet or more were observed on a north-south ridge about three-fourths of a mile south of Fortyeight Creek. They were dug at different places on the crest and as far as 40 feet below the crest. They penetrated clay and chert and two of them revealed gravel that is composed of well-rounded chert pebbles. Five of them revealed brown iron oxide in different quantities; the other five revealed none. The deepest pit, 26 feet deep, which is on the east slope of the ridge, was not observed. It is said to have passed through ore from the surface to the bottom and not to have passed entirely through it.

More than a dozen pits, of which 14 were observed, are on a north-south ridge which is just east of a northward-trending hollow that separates this ridge from the above-described ridge. They have been dug over a considerable area on the crest and west slope. They range in depth up to 20 feet or more. Some of them penetrated clay, others penetrated clay and chert. and the rest penetrated clay, chert, and gravel. Eight of them revealed brown iron oxide in considerable quantity but the others revealed little or none of it.

The iron ore on these two ridges is of good quality but the prospecting that has been done thus far has apparently not proved the occurrence of a workable ore body. Further prospecting to determine the size of the ore bodies would however be justified from the amount of ore in sight.

Dr. Buchanan reports the occurrence of iron ore on the surface at different places on the part of his property that lies north of Fortyeight Creek. None of these places have been prospected and they were not visited by the writer.

Hughes prospect (48)

The Hughes prospect is on property which is owned by Judge Taylor Hughes of Columbia, Tenn., and is on the crest of a ridge on the east side of Chisholm Creek, about 1½ miles north of the mouth of Reed Patch Creek and 7 miles north of Pinkney. The ridge trends in a northeast direction and is capped with residual clays and cherts derived from the St. Louis limestone and with small pebbles of chert and quartz. Of these materials the clays predominate.

Possibly 50 prospect pits which were dug in 1907 were examined by the writer in 1913. They were 10 feet or more in depth and were made here and there along the ridge for fully a quarter of a mile. They penetrated the clays and other materials mentioned above. About half of the pits visited revealed iron ore; some of the others were not sunk deep enough to reach the ore horizon. Shot ore is revealed on the surface on the crest of the ridge and in the pits on the crest, whereas lump ore is revealed in the pits on the slopes. The ore is a brown oxide of iron, is hard and is generally free from sand, but the lump ore at places contains fragments of chert. Such fragments, however, are soft, so that they may be easily separated from the ore.

Further prospecting was done in 1917, by G.W. Boyd, of Waynesboro, Tenn.

Flippo, Bruton, Kidd and Biggs tracts

Iron ore is said to occur on a tract of land owned by Patrick Flippo, which is on the west side of Chisholm Creek and northwest of the Hughes tract. Some prospecting has been done on the tract.

A tract which is owned by Will Bruton adjoins the south side of the Flippo tract and is reported to contain iron ore. A small amount of prospecting has been done.

Iron ore is also reported on a tract belonging to Joe P. Kidd, which is just south of the Bruton tract, and some prospecting has been done for such ore.

The Biggs tract which is just west of the Kidd tract is said to contain surface showings of iron ore, but thus far no prospecting has been done.

None of the tracts here mentioned were visited by the writer.

Prospect of Sheffield Iron Corporation (49)

An ore-bearing tract which is said to belong to the Sheffield Iron Corporation is on the crest of a westward-trending spur 2½ miles west of Lodi. Iron oxide in small fragments known as shot ore is revealed in red clay at places in a wagon road for a distance of about half a mile along the crest of the spur and it is also revealed in a few small pits which are also on the crest. Further prospecting will be required to determine the size of the ore body.

Prospect on Double Branch (50)

An iron-ore prospect was observed on the crest of a ridge 3 miles west-northwest of the mouth of Double Branch. The ridge is on the north side of this stream. The pits reveal brown iron ore in red clay in which there are fragments and pebbles of chert. Not enough prospecting has been done to determine the size of the ore deposit.

Prospect of Wayne County Land Co. (51)

Considerable prospecting for iron ore has been done on the crest of the ridge about half a mile south of Moon postoffice. The property on which the prospecting has been done is owned by the Wayne County Land Co. of Nashville, Tenn. The ore is a brown oxide of iron and occurs in the residual clay and chert of the St. Louis limestone and in gravel. It is exposed not only on the crest of the ridge but also on its slopes and along streams in hollows that dissect the ridge. The ore observed on the surface and in the shallow openings is of good quality and is composed of small particles and large masses. The exposures and openings indicate that the ore-bearing area is probably half a square mile in extent and systematic prospecting will perhaps reveal one or more ore bodies of workable size.

McDonald-Robinson prospect (52)

An ore-bearing tract, most of which is owned by Neal McDonald and the rest by Andrew Robinson, is on the crest of a ridge 3 miles north-northwest of Pinkney. Brown iron ore consisting entirely of shot ore is revealed in red clay in gullies by the roadside, and on the surface. A recently dug well on the top of the ridge at the place where Mr. McDonald was planning to build his new residence showed the clay to be 10 feet thick and to be underlain by chert. Fragments of lump ore of good quality were removed from the well. Some chert fragments and pebbles occur in the clay. The ore-bearing tract apparently extend over several acres but whether or not iron ore is in minable quantity can be determined only by prospecting.

Wright mine (53)

The Wright mine is 1½ miles east of Pinkney. The property on which the mine is located consists of 200 acres. In 1888 Pinkney Wright, the owner after whom the mine was named, sold the property to William Whitthorne, of Columbia, Tenn. Later it was acquired by the Lawrence Iron Co., which still owns the property. J. Craig McClanahan who leased the property from the company began the mining of iron ore in 1897 and continued it until 1900 when his lease expired. He produced 506,000 tons of ore which was purchased by the Tennessee Coal, Iron & Railroad Co. and shipped to Sheffield, Ala., and South Pittsburg, Tenn. Thomas Worthington, of Birmingham, Ala., prospected the property very thoroughly from December, 1918 to May, 1919, and as will be noted below he found much minable ore still available in the mine.

The mine consists of irregular cuts all of which are on crooked ridge crests. The aggregate area of the cuts is 40 acres and their average depth is about 15 feet. The cuts and prospect pits reveal a gray loam 1 to 2 feet thick at the surface, then 20 to 25 feet of red clay, and below this yellow clay. Pebbles, fragments, and boulders of chert are numerous in much of the yellow clay but are generally wanting in the red clay and surficial loam. Pockets of yellow and red sand measuring many feet long, wide, and thick are present in the clay but are far less numerous than they are at the Ironsides, Pinkney, and Little Hill mines.

The ore occurs in the sand and clay as loose disconnected fragments near the surface and as branching veins and large masses in the deeper parts of the openings. As it comes from the mine it consists of masses of many sizes ranging from a fraction of an inch to several feet in diameter; the different sizes are known as shot, lump, and boulder ore. It is brown iron oxide and is hard and compact, though the boulder ore contains many irregular cavities. Most of it is free from sand and chert fragments and pebbles.

Much minable ore has been left in the bottoms of the cuts and in unworked areas. The estimates by different persons of the quantity

of such ore ranges from 500,000 tons to 4,000,000 tons, but it is reported that the estimate of Thomas Worthington of Birmingham, Ala., who prospected the property in a systematic way was 750,000 tons.

The ore-bearing clay was mined with four steam shovels and was then hauled on tram roads to two washing plants where it was treated.

Pinkney mine (54)

The Pinkney mine, also known as the Tucker Hill or Tucker mine, is on the ridge just west of the village of Pinkney. It was first operated in 1887 by J. Craig McClanahan who leased it from the Lawrence Iron Co., the owner, and its operation was continued by him most of the time until 1900 when his lease expired. The Lawrence Iron Co. operated the mine much of the time from about 1902 to 1912 under the name Pinkney Mining Co. Also a small amount of work has been done within the last 3 or 4 years. The superintendent of the mine for the Pinkney Mining Co. is Daniel King.

Mr. McClanahan produced 356,000 tons of iron ore from an area of 12 acres, and the Pinkney Mining Co. produced 606,500 tons from an area of 25 acres, though part of this output was obtained by reworking the 12 acres that had been worked earlier by Mr. McClanahan. The total production of the mine is therefore 962,500 tons.

Thomas Worthington of Birmingham, Ala., prospected the property very thoroughly between December, 1918 and May, 1919, and, as will be noted below, he found much minable ore still available in the mine.

The mine consists of open cuts which have been made at places along the crest of a north-south ridge for a distance of about half a mile, though one small cut with an area of half an acre was made on the east hill slope between 150 and 200 feet below the crest of the ridge. This small cut is just north of and below the washing plant. The aggregate area of the cuts is about 25 acres and their depth ranges from several feet to 50 feet.

The part of the ridge on which the cuts north of the washing plant were made is known as Boarding House Hill. These cuts at the deepest places are 20 to 25 feet deep. They reveal red clay in which there are many pockets of sand and gravel and also reveal considerable chert which is especially abundant in the lower parts of the cuts. The ore is irregularly distributed through the materials just named and consists of the three kinds, shot, lump, and boulder ore of which the first two are compact but the last is porous. The ore that occurs in the pockets of sand contains much sand and is too siliceous to be mined.

The cuts on the part of the ridge that is west and southwest of the washing plant are as much as 50 feet deep and their depth over a considerable area will average between 40 and 50 feet. The ore-bearing material revealed by them is mainly red clay. Near the surface the clay

contains a comparatively small quantity of chert fragments and pebbles but in the lower parts of the cuts these predominate over the clay. Furthermore the clay contains numerous lenses or pockets of sand as much as 35 feet thick. The sand in these lenses is cross bedded, and contains many flakes of mica, thin horizontal layers of plastic white clay, and a few well-rounded pebbles of chert and quartz. The lenses are not mined because the ore in them is too siliceous to be of value. In consequence of this some of them are left as pinnacles in the cuts. A picture of one of these pinnacles is shown in Plate III, A.

The ore is brown iron oxide and occurs as disconnected fragments of different sizes at and near the surface and as veins and large irregular masses in the lower parts of the cuts. Much of the ore, especially the larger masses, contain clay and many chert fragments and pebbles, but it was mined and treated in the washing plant.

The minable ore that has been left in the mine occurs in and near the old workings and in unworked areas which, according to Mr. King aggregate 4 or 5 acres. Mr. King told the writer in 1914 that his estimate of ore still in the deposit is 400,000 tons. The estimate of Thomas Worthington which was based on the results of systematic prospecting that was done in 1918 and 1919 is said to have been 500,000 tons.

The ore that was marketed by the Pinkney Mining Co. is said by Mr. King to have averaged 47 per cent of iron, .70 per cent of phosphorus, and 17.50 per cent of solubles. The first analysis given below represents the composition of a sample of the massive ore in the lower parts of the cuts and the second one the composition of the shot ore at and near the surface. The samples were collected by N. F. Drake.

Analyses of iron ore from the Pinkney mine

(Paul C. Bowers, analyst.)

	1	2
Iron (Fe)	54.17	56.07
Phosphorus (P)	1.302	.361
Sulphur (S)	.004	.024
Silica (SiO_2)	6.01	7.06

Mr. McClanahan operated the mine at times with two steam shovels and at other times with three steam shovels. The crude ore was treated in a washing plant which was supplied with water from Chisholm Creek. The washed ore was shipped to Sheffield, Ala.

The Pinkney Mining Co. used two steam shovels in the mine and operated a washing plant on the east hill at the west edge of the village of Pinkney. The plant was erected at a cost of $150,000 and was equipped with two double log washers, four sets of jigs, a crusher, screens, and a picking belt. It has remained idle since 1912 and has become so delapidated that the complete rebuilding of the plant would be required before it could be operated again. The ore produced by the Pinkney

Mining Co. was shipped to Cumberland, Clarksville, Cowan, and Sheffield furnaces.

The following information about the fine waste ore on the dumps near the washing plant of the Pinkney Mining Co. has been furnished by Mr. King.[1]

"On the east side of the railroad we have a large body of waste ore that came though the jig sashes and over the ends of the logs. Some 6 or 7 years ago we sent about half a ton of it to Fort Wayne, Ind. It analysed 42.30 per cent. of iron. It put over an "Overstrom" table from which there was a loss of less than 16 per cent of the ore but the ore from the table analysed 49.50 per cent of iron. The thousands of tons of fine waste on the hillsides near the washing plant contain from 32 to 40 per cent. of iron. The percentage of iron in it can be increased to 40 to 44 by means of a Hancock jig and will have a market some day.

"Within the last 3 or 4 years we dry screened and hand picked, about 6,000 tons from the pile by the old ore bin. It averages, in the pile 36 to 38 per cent. of iron, but after screening and picking it averaged between 42 and 44 per cent. of iron. In the fall of 1920 the farmers got out about 500 tons of ore from the pile that averaged 44.93 per cent. of iron and .58 per cent. of manganese making the selling per centage 45.51. They made as high as $5 to $6 a day and would be at it yet if the furnaces remained in blast."

Ironsides mine (55)

The Ironsides mine, also known as the West Point mine, is on the crest of a hill 1½ miles northeast of West Point. It is owned by the Sheffield Iron Corporation, formerly known as the Sheffield Coal & Iron Co. It was opened by the West Point Mining & Manufacturing Co.; but was soon acquired by Alexander Berger who sold it to the Sheffield Coal & Iron Co. This company operated the mine until 1904, and since then the mine has remained idle. Its production has been 650,000 tons of iron ore.

The mine is a cut which has an area of 16 acres and which averages 30 feet or more in depth. The upper parts of the sides of the cut reveal red clay whereas their lower parts reveal yellow clay; though the surficial loam 1 to 2 feet thick is gray in color. The clay is comparatively free from chert fragments and pebbles but contains them at many places in the lower part of the cut. Pockets of yellow to red sand 25 feet or more thick and 100 feet or less long and wide are fairly numerous. When they were encountered the steam shovel passed around them so that they were left as pinnacles rising above the bottom of the cut.

The iron ore is brown iron oxide, is generally hard and compact and it once formed veins and reticulated masses in the clay and sand but these veins and masses have been largely broken up in weathering so that the ore occurs in masses of different sizes. It occurs as lump and shot ore near the surface and as boulder ore in the lower parts of the cut. The ore that is present in the pockets of sand contains so much sand that

[1]Letter dated Feb. 26, 1921.

it was not mined and some of that in the lower parts of the cut contains chert pebbles and fragments. Many boulders of sandy and pebbly ore that were found in the mining were not taken to the washing plant but were left in the cut.

The ore deposit at this mine proved to be very rich. During the first year of its operation the ratio of ore-bearing material to washed ore averaged one ton of washed ore for every 2 yards of loose ore-bearing material and during the second year it averaged one ton of washed ore for every 2½ yards of loose ore-bearing material. The marketed ore is said to have averaged more than 50 per cent of iron and much of it is said to have averaged 52.50 per cent of iron, .83 per cent of phosphorus, and 10.10 per cent of insolubles.

The ore was mined by means of a steam shovel, and was hauled in tram cars to the washing plant just north of the mine where it was beneficiated. Water for the plant was obtained from Chisholm Creek. A spur railroad about 1½ miles long ran from West Point to the plant. The washing plant was dismantled when the operation of the mine was stopped and the rails were also removed from the spur at that time.

Neal property

The P. A. Neal (formerly W. W. Neal) property joins the properties on which the Ironsides and Wright mines are located and is reported to show iron ore on the surface. No prospecting has been done.

Sharp (56), Wisdom (58), Drake (59), and Burkett (57) mines

The Sharp, Wisdom, Drake, and Burkett mines are on a large tract of land east and northeast of Pinkney, which is owned by the Napier Iron Works. The operation of the Sharp mine was begun in 1888 by Thomas Sharp of Nashville, Tenn., and by a Mr. Smith of Dayton, Ohio, who leased the property from the Boswell heirs, the owners. They operated under the name of the Smith and Sharp Mining & Manufacturing Co. They were succeeded by the West Point Mining & Manufacturing Co., and they by the Napier Iron Works which purchased the property from the Boswell heirs in 1904. The Napier Iron Works opened and worked the Wisdom, Drake, and Burkett mines beginning in 1905 and quitting in 1912. The aggregate production of the four mines here named was 400,000 tons of iron ore. Of this the Sharp mine yielded between 135,000 and 140,000 tons and the other mines between 260,000 and 265,000 tons.

The Sharp mine (56) is on the crest of a ridge 1½ miles east of Pinkney. It is an irregular cut which has area of between 8 and 10 acres and which is as much as 35 feet deep. The Burkett mine (57), which is a cut 250 feet long by about 100 feet wide, is on the crest of a ridge half a mile northeast of the Sharp mine. The cut at the time of

visit, April, 1920, was partly filled with water and the banks that stood above the level of the water were 10 feet high. The small size of the cut suggests that its production did not exceed 5,000 tons of iron ore. The Wisdom mine (58) consists of several irregular cuts on the crest of a ridge 1¼ miles north of the Sharp mine and 2 miles northeast of Pinkney. The aggregate area of the cuts appears to be between 15 and 20 acres and their depth ranges from several feet to 25 or 30 feet. The Drake mine (59) is a cut with an area of 2½ to 3 acres and a depth of as much as 25 feet on the west point of a southwestward-trending ridge half a mile east of Pinkney.

The deposits of iron ore at these mines are very similar. The cuts reveal a gray surficial loam 1 to 2 feet thick, then 20 to 25 feet of red clay, and below this yellow clay. Pebbles, fragments, and boulders of chert are generally absent in the red clay but are numerous at places in the yellow clay. Pockets of yellow and red sand measuring many feet in their three dimensions are common but are less numerous than they are at the Little Hill, Pinkney, and Ironsides mines.

The iron ore which is brown iron oxide is irregularly distributed through the clay and sand as fragments of different sizes near the surface and as veins and large irregular masses in the lower parts of the cuts. The ore as it was taken from the mine consisted of masses of many sizes ranging from a fraction of an inch to several feet in diameter and it, according to the size of the masses, is known as shot, lump, and boulder ore. The ore is hard and most of it except the large masses is compact. Such masses are more or less porous and generally contain clay and chert fragments and pebbles. All of the ore that occurs in the pockets of sand is very siliceous and was therefore not mined. The ore-bearing clay has been removed from around some of these pockets so that they have been left as pinnacles in the cuts.

It appeared to the writer that only about one-third or less of the original available ore has been left in the deposits at these mines but it appeared that a larger proportion might still be available at the Drake and Wisdom mines. He was told, however, that the deposits had been pretty well worked out under the conditions that existed at the time that the mining was done.

The mining was done with steam shovels and the ore-bearing material was hauled on tram roads to one or more washing plants where it was treated. One of these plants was in the head of a hollow just south of the Wisdom mine. The one or more washing plants were torn down many years ago and the steel rails have also be removed from the tram roads and from railroad spurs that ran from Pinkney to the washing plant near the Wisdom mine. The ore that was produced by the Napier Iron Works was shipped to Napier Furnace, Napier, Tenn.

Hessemer No. 1 (61) and No. 2 (60) mines

The Hessemer No. 2 mine is on the crest of a north-south ridge one-fourth mile southwest of Pinkney and 1½ miles north-northwest of West Point. It joins the south side of the Pinkney or Tucker mine. The Hessemer No. 1 mine is on the crest of the first north-south ridge west of Hessemer No. 2 mine.

These mines are owned by the Sheffield Iron Corporation which was formerly known as the Sheffield Coal & Iron Co. The operation of the mines was begun in 1902 by the latter company and was continued until about 1907, since which time they have remained idle. The production of iron ore from the Hessemer No. 1 mine was 170,000 tons and that from the Hessemer No. 2 mine was 130,000 tons, all of which was shipped to Sheffield, Ala.

The Hessemer No. 2 mine consists of several cuts which extend along the crest of the ridge from a quarter to half a mile. The cuts appear to comprise an area of 10 to 12 acres and they range in depth from about 10 feet to 35 feet. The character of the ore and ore-bearing material is the same as that at the Pinkney and Ironsides mines. The ore which is brown iron oxide occurs as single and reticulated veins and large masses in the lower parts of the cuts and as fragments generally of small size at and near the surface. (See Plate VI, B). The ore according to the size of its masses as they come from the mine would include shot ore, lump ore, and boulder ore. All of it except the large masses is compact and hard and is generally free from clay, chert, sand, and gravel. The large masses are porous and contain more or less of these impurities. Although ore with such impurities was mined and treated in the washing plant many huge boulders of it were discarded and left in the cuts. The ore occurs in red sand and clay, but in the deeper parts of the cuts there are many fragments, boulders, and pebbles of chert. The ore in the sand, as would be expected, contains much sand and such parts of the deposit were not mined so that they now rise as pinnacles above the floors of the cuts. It was mined with a steam shovel and conveyed to the washing plant which was located on the southwest point of the ridge. The ore-bearing area has not been worked over entirely and there is apparently much available ore yet to be mined.

Hessemer No. 1 mine consists of several irregular cuts which extend along the crest of the ridge for about 1,500 feet. They apparently comprise an area of 7 or 8 acres and are as much as 30 feet deep. The ore and ore-bearing materials are the same as those at Hessemer No. 2 mine. The crude ore was mined with a steam shovel and was hauled on a tram road to a washing plant on the southeast point of the ridge where it was treated. Water for the plant was pumped a distance of about 1 mile from Chisholm Creek. The minable ore at this locality is said to have been exhausted.

The washing plants for these mines have been dismantled and the spur railroad 2 miles long from West Point over which the marketed ore was shipped has been torn up.

Little Hill mine (62)

The Little Hill mine is on the crest of a hill half a mile northwest of Pinkney. Beginning in 1902 it was operated for a few years by the Pinkney Mining Co. The superintendent of the mine was Daniel King. It was later sold to J. J. Gray, jr., and its operation was begun by him in 1906 and was continued until 1911 since which time it has remained idle. The combined production of the Little Hill and Dodd mines by Mr. Gray is reported to have been 150,000 tons of iron ore.

The mine is an irregular cut which has an area of apparently 4 or 5 acres and a depth that ranges from a few feet to 40 feet.

Besides iron ore the cut reveals a considerable variety of materials of which the most abundant is clay which is red in the sides of the cut and yellow in its bottom. Much angular chert and many well-rounded chert pebbles occur in the yellow clay but are generally absent in the red clay. Also horizontal lenses of yellowish-red sand as much as 15 feet or more thick are common. When mining was discontinued in 1911 all of the minable ore was considered to have been taken out.

The iron ore which is brown iron oxide occurs in the form of shot and lump ore, and is irregularly distributed through the clay and other materials that have just been described. It is generally compact and hard; but the larger masses are porous and contain clay and some chert and pebbles. Many parts of the deposit contain much sand and others contain very little ore; they were not mined in consequence of which the cut is very irregular in shape.

The crude ore was mined with a steam shovel and was hauled on a tram road to the washing plant which was located at the south edge of the mine and on the south slope of the hill. The ore from the Dodd or Gray mine was also treated in this plant. Water for the plant was obtained from Chisholm Creek.

Dodd mine (63)

The Dodd mine, also known as the Gray Mine, is 1¼ miles west of Pinkney and 2½ miles northwest of West Point. It was worked by J. J. Gray, jr., from 1907 until 1913 or 1914. Mr. Gray's production of iron ore from this and the Little Hill mine is reported to have been 150,000 tons of iron ore.

The mine is an irregular cut with an area of 3 or 4 acres on the south slope and west point of a ridge. The cut ranges in depth from 10 to 20 feet and its lowest point is about 100 feet below the crest of the ridge.

The ore which is brown iron oxide is compact and hard, is comparatively free from sand, and is mostly in the form of lump and shot ore

but includes some boulder ore. It occurs in red clay in which there is much chert, some pockets of gravel and a few pockets of sand. Some ore was visible in 1920 in the sides of the cut and in gullies in the bottom of the cut but the minable ore in the deposit was considered to have been exhausted when mining was discontinued in 1913 or 1914.

The ore was mined by a steam shovel and hauled on a tram road to a washing plant at Pinkney, in which ore from the Little Hill mine was also treated. When the mine was abandoned the steel rails of the tram road were removed and the washing plant was dismantled.

Hopkins prospect (64)

The Hopkins prospect is on the crest of a ridge north of Hessemer No. 1 mine and west of the Pinkney mine. It is on a tract that is owned by the Sheffield Iron Corporation. Test pits have been made here recently and are said to have revealed much iron ore. The tract was not visited by the writer.

Couch mine (65)

The Couch mine is on the crest of a ridge 1 mile west of Rhodes Hill station and 2½ miles north-northeast of Wayland Springs. It was worked from 1909 to 1912, inclusive, by the Sheffield Coal & Iron Co., the owner, which produced 196,000 tons of iron ore with an average iron content of 48.87 per cent. The mine has remained idle since 1912.

The mine consists of a cut with an area of 7 acres. (See Plate VI, A). The depth of the cut ranges from a few feet to 30 feet but in most parts is between 20 and 25 feet. The ore which is brown iron oxide occurs in clay and consists of the three varieties known as shot, lump, and boulder ores and at places there is bombshell ore. Besides ore the clay contains some pockets of sand and gravel and many chert fragments and boulders.

Sand and gravel are present in the ore at places and at some places they are so abundant that the silica content of the ore is too high for it to be marketed. Many boulders of this sandy and pebbly ore as much as several feet in diameter were discarded and left on the floor of the cut. An area of ore near the middle of the cut was too sandy to be mined and was left as a pinnacle after the minable ore had been removed from all sides of it. This pinnacle is shown in the left part of the accompanying photograph (Plate VI, A) and many of the discarded boulders of siliceous ore are also shown in it.

Although the deposit was mined out under the conditions that existed at the time work was discontinued in 1912 much available ore remains in the deposit and may be mined profitably at some future date.

The ore was mined with two steam shovels and then hauled in tram cars to a washing plant which was located three-fourths of a mile west of Rhodes Hill where it was concentrated. The plant was well equipped

and its output was 500 to 600 tons a day. Water for it was pumped from Factory Creek at Rhodes Hill.

Gresham mine (66)

The Gresham mine is on the crest of a ridge 1 mile north of Geneva station and 5 miles west of West Point. It was worked by the Sheffield Coal & Iron Co. beginning in 1913 and ending in 1915 and it produced during this time 65,138 tons of iron ore. It was sold in 1919 or 1920 to the Napier Iron Works.

The mine consists of a very irregular cut which has an area of 10 to 12 acres and which ranges in depth from a few feet to 18 feet. The ore is brown iron oxide and occurs mostly as shot ore and lump ore but there is some boulder ore. It is in red clay in which there is at places sand and chert fragments and pebbles. Some of the ore itself contains chert fragments and pebbles and sand. Boulders of ore with these impurities were discarded during the mining and may now be seen on the floor of the cut. The following analysis shows the composition of a sample of iron ore collected by N. F. Drake from this mine.

Analysis of iron ore from the Gresham mine

(Paul C. Bowers, analyst).

Iron (Fe)	56.39
Phosphorus (P)	.788
Sulphur (S)	.014
Silica (SiO_2)	3.83

The ore body that was workable from 1913 to 1915 was probably exhausted but nevertheless much ore remains and may perhaps be mined profitably at some future date. Pits and shot ore on the surface indicate that the ore deposit extends along the crest of the ridge for about one-fourth mile southeast of the cut.

The Sheffield Coal & Iron Co. mined the ore with two steam shovels and then hauled it on a tram road 7 miles long to the washing plant near Rhodes Hill station where it was concentrated. This plant had been used earlier for concentrating the ore from the Couch mine.

Gambrel prospect (67)

The Gambrel prospect is just west of the Gresham mine. The agricultural right of the property on which the prospect occurs is owned by Mrs. Laura Gambrel and the mineral right is owned by Dr. J. B. Powell of Nashville, Tenn. Small fragments of brown iron oxide were observed at places on the surface and in one small pit on the crest of a ridge. Whatever ore is found in future prospecting will probably resemble in quality and occurrence that at the Gresham mine.

Hollis prospect (68)

The Hollis prospect is one-fourth mile west of the Gresham mine and half a mile north-northwest of Geneva. The mineral right of the

property on which the prospect occurs is owned by John Gambrel and Richard Olive.

A few pits have been made at widely separated localities on and near the crests of the hills on this tract. Those that were examined revealed a small amount of brown iron oxide in red clay, But one pit that was made on the south point of a hill by the roadside revealed considerable ore. The pit was dug to a depth of 10 feet and most of the material removed from it was hard, compact brown iron oxide; the rest was clay and chert. It is said that the pit did not pass through the ore. Brown iron ore in large and small fragments covers the surface in the vicinity of the pit and is also reported to occur on the surface along the crest of the hill for half a mile north of the pit.

Elting mine (69)

The Elting mine is on the crest of a ridge three-fourths of a mile south of Geneva and 1½ miles northwest of Corning. The property on which it is located is owned by N. C. Elting and was leased a few years ago to the Napier Iron Works. This company operated the mine beginning late in 1917 and ending sometime in 1918. The production of iron ore during this time was 25,651 tons.

The mine is a north-south cut 500 feet long which comprises an area of about 3 acres and averages between 10 and 15 feet deep. It was made in red clay in much of which there are boulders and small fragments of soft to hard chert. Besides chert the clay contains a few pockets of chert pebbles and also pockets of fine sand. The ore which is brown iron oxide is lump ore and shot ore and is disseminated as fragments and veins through the clay, chert and gravel, and is generally confined to the lower part of the cut. The clay, chert and gravel contain very little ore within 10 feet of the surface. The ore that was shipped is stated by R. M. Davis, of the Napier Iron Works, to have averaged between 45 and 48 per cent of iron.

Although the ore body at this locality apparently covers a much larger area than that in the cut and has not been exhausted all of the ore that could be mined by using a steam shovel under present conditions was mined.

The ore, as just stated, was mined by means of a steam shovel and then hauled on a tram road 1.4 miles to the washing plant which is about 1 mile west of Corning. This plant treated ore not only from the Elting but also from the Robinson and J. B. Powell mines and from the mine of the Tennessee Charcoal Iron Co. It is briefly described above under the description of the Robinson mine. The washed ore from this mine was shipped to Napier Furnace, Napier, Tenn.

J. B. Powell mine (70)

The J. B. Powell mine owned by Dr. J. B. Powell of Nashville, Tenn., is on the crest of a ridge and adjoins the southside of the Elting mine. It is three-fourths of a mile south of Geneva and 1½ miles northwest of Corning. The Napier Iron Works, the lessee, operated this mine from February, 1917, until 1918, and produced 28,618 tons of iron ore.

The mine consists of four irregular cuts, 10 to 20 feet deep, which comprise an area of about 5 acres. The ore in its character and occurrence is similar to that at the adjoining Elting mine. Although there is apparently much ore left in the deposit the Napier Iron Works removed all that could be mined under present conditions.

The deposit was worked by a steam shovel and the crude ore was hauled over a tram road to a washing plant which is about 1 mile west of Corning. The washed ore from the plant was shipped to Napier Furnace, Napier, Tenn. It is stated by R. M. Davis of the Napier Iron Works to have averaged between 45 and 48 per cent of iron. The following analyses of ore[1] from this property were furnished by Dr. Powell before any mining was done on it.

Analyses of iron ore from the J. B. Powell mine

	1	2	3
Iron (Fe)	54.20	55.60	55.54
Phosphorus (P)	.80	1.02	.80
Insolubles	6.00	4.20	4.36

1. Analysis by The Sheffield Coal & Iron Co.
2. Analysis by The Red River Iron Co.
3. Analysis by The Brown Laboratories, Inc.

Mine of Tennessee Charcoal Iron Co. (71)

A mine which is owned by the Tennessee Charcoal Iron Co. is on the crest of a ridge half a mile southwest of the J. B. Powell mine and is 1½ miles west-northwest of Corning. It was worked by the Napier Iron Works, the lessee, beginning in January, 1918, and ending March, 1918, when it was abandoned. The production of ore during that time was 7,000 tons.

The mine consists of 2 cuts, 700 feet apart. The aggregate area in them is between 1½ and 2 acres and their depth ranges from a few feet to 15 feet. The ore occurs as shot ore and lump ore in red clay in which there is some chert and is apparently of good quality. The ore body has not been worked out but all of the ore that was available under present conditions by using a steam shovel has been mined.

The crude ore was hauled from the mine on a tram road about 2 miles long to the washing plant 1 mile west of Corning. The washed ore was shipped to Napier Furnace, Napier, Tenn.

[1]Purdue, A. H., The iron industry of Lawrence and Wayne countries: The Resources of Tennessee, vol. 2, No. 10, p. 385, 1912.

Robinson mine (72)

The Robinson mine, also known as the White-Littrell mine, is 2 miles southwest of Corning. It is owned by Noah White of Iron City and J. Allen Littrell, of Pulaski, Tenn. The tract on which it is located was leased a few years ago to the Napier Iron Works which opened the mine in February, 1918, and which has been operating it much of the time since then. The production of iron ore by this company up to the end of December, 1920, was 134,610 tons.

The mine is a long irregular cut trending S. 70° W. along the crest of a ridge. When the cut was examined in April, 1920, it was 1,700 feet long, comprised an area of 10 acres, and ranged in depth from about 10 feet to 35 feet.

The ore is brown iron oxide and includes both shot and lump ore. It occurs as a network of thin veins and as single veins in clay and greatly fractured chert and also occurs as fragments in clay at and near the surface. It is generally compact and hard but some of it is porous (see Plate X, B) and some contains chert fragments. The ore that has been shipped is stated by R. M. Davis of the Napier Iron Works to have averaged between 45 and 48 per cent of iron. The clay and chert are intermixed but there is in general more chert in the lower part of the cut than in the upper part. Also the clay near the surface is dark red whereas it is yellowish red in the lower part of the cut. A fairly large number of pockets of gravel which are composed of well-rounded chert pebbles are encountered in mining, especially in the lower part of the cut; at one place the writer observed a flat-lying lens of sand 10 feet thick; and there are also some irregular pockets of wad a few feet long.

Prospect pits in areas adjoining the cut indicate that there is much available ore yet to be mined, though at the time of visit the workable ore body was expected to be mined out within the next several months.

The ore is being mined with two steam shovels and is hauled on a tram road 1¼ miles long to the washing plant which is about 1 mile west of Corning. Four locomotives are used on the tram road. The plant is equipped with a McCanahan-Stone double log washer, a crusher, two sets of jigs, screens, and a picking belt. The washed ore from the plant is shipped to Napier Furnace of the Napier Iron Works at Napier, Tenn.

Hardwick mine (73)

The Hardwick mine owned by the Southern Tennessee Development & Mining Co. is on the crest of a spur three-fourths of a mile west of Hardwick station on the Tennessee Western Railroad, and is 200 feet above Hardwick.

The property on which the mine is located was extensively prospected by pits in 1914. A washing plant equipped with a 2-log washer and screens capable of handling 2,500 tons of washed ore per month

was erected just north of the mine in 1917 and 1918 by the Ohio Mining Co. and a spur railroad was built from Hardwick to the washer. The mine was operated for a short time by this company in 1918 and was operated by the Tennessee Valley Iron & Railroad Co. for a short time early in 1920. The last named company was reorganized in June, 1920, becoming the Tennessee Charcoal Iron Co., and since then it has resumed the operation of the Hardwick mine. The marketed ore is being shipped to Collinwood where it is used in Anna (a charcoal) Furnace that is owned by this company. The production of ore during the year 1920 was 6,500 tons.

The principal cut, 150 feet long, 30 feet wide and 20 feet deep at the deepest place which was made by a steam shovel, started on the north hillslope and trends S. 15° W. In its north part it passed through red clay with chert pebbles and fragments with very little ore but at its south end it encountered lump and shot ore in large quantity in red clay in which there is some chert. A smaller cut was made in ore-bearing clay 150 feet west of the one just described. The prospect pits which had been made at other places penetrated red clay with chert fragments to a depth of as much as 30 feet deep, and most of them revealed ore in minable quantity. They and the cuts indicate that the workable area probably comprises 4 acres, and that the ore-bearing clay averages 10 feet or more thick. The ore consists of the brown and red oxides of iron, mostly the former. It occurs in large masses and small particles and is generally free from sand.

A hill just south of the mine reveals ore in the clay banks of uprooted trees. Prospecting has, however, not been done here.

Two ore-bearing tracts—one of 1½ acres, and the other of half an acre—are on the crest of a ridge about one-fourth mile southeast of the washing plant. The quantity of brown iron ore as revealed in the pits is fair and the ore-bearing clay will probably average 5 feet thick over the 2 acres in these tracts.

J. B. Powell prospect No. 1 (74)

The J. B. Powell prospect No. 1 owned by Dr. J. B. Powell of Nashville, Tenn. and leased by the Napier Iron Works is on the crest of a ridge 1 mile west-northwest of Hardwick and is just west of the Hardwick mine. Brown iron ore including both shot ore and lump ore is revealed through the entire depth of two pits, one being 7 feet deep and the other 25 feet deep, and is also revealed on the surface over an area of about 3 acres. It is hard and free from sand, is apparently of good quality, and occurs in red clay, in which there are chert fragments and pebbles. The deposit on this tract is simply a westward continuation of the deposit at the Hardwick mine.

J. B. Powell prospect No. 2 (75)

The J. B. Powell prospect No. 2, owned by Dr. J. B. Powell of Nashville, Tenn., and leased by the Napier Iron Works, is on the crest of a northwest-southeast ridge, 1 mile west-southwest of Hardwick. Brown iron oxide in the form of lump ore and shot ore is present in considerable quantity on the surface over an area of several acres in an old field and it was revealed in red clay in a gully and in the two small pits. It is compact and hard and is mostly, though not entirely, free from sand and gravel. The presence of some chert fragments on the surface suggests that they also occur in the clay. Although the ore body may be of workable size further prospecting will be necessary to determine its depth and extent before any mining is begun.

Littrell-White prospect (76)

The Littrell-White prospect, owned by Noah White of Iron City and J. Allen Littrell of Pulaski, Tenn., and leased to the Napier Iron Works, is on the crest of a north-south ridge 1 mile north of the mouth of Swannigein Creek and on the west side of the stream. Although very little prospecting has been done here the few pits and the presence of iron ore on the surface show that the iron ore deposit probably covers an area of 4 or 5 acres. The ore is brown iron oxide, is generally compact and hard, and consists of both lump and shot ore. It occurs in red clays and contains some soft chert and sand though most of the deposit is free from these impurities. The proportion of ore in the clay, the quality of the ore, and the size of the deposit will apparently justify mining at this locality.

Napier Iron Works prospect (77)

An ore-bearing tract owned by the Napier Iron Works is on the crest of a hill one-fourth mile east of the mouth of Swannigein Creek. Preliminary prospecting by means of pits 10 feet or less deep was done in 1910 by Paul Seavy and E. L. Lull. The ore is brown iron oxide and consists of shot ore of good quality disseminated through red clay. It occurs over an area of about 12 acres and appears to be in minable quantity.

Berlin prospect (78)

The Berlin prospect is 3 miles northwest of Iron City and although very little work has been done the few pits and the presence of iron ore on the surface indicate that such ore underlies an area of perhaps 25 acres on the crest of a northwest-southeast ridge. Thorough prospecting however will probably show that ore in minable quantity underlies only a fraction of this area. The ore as revealed on the surface at the time of visit consisted of brown iron oxide in fine particles known as shot ore and occurs in red clay.

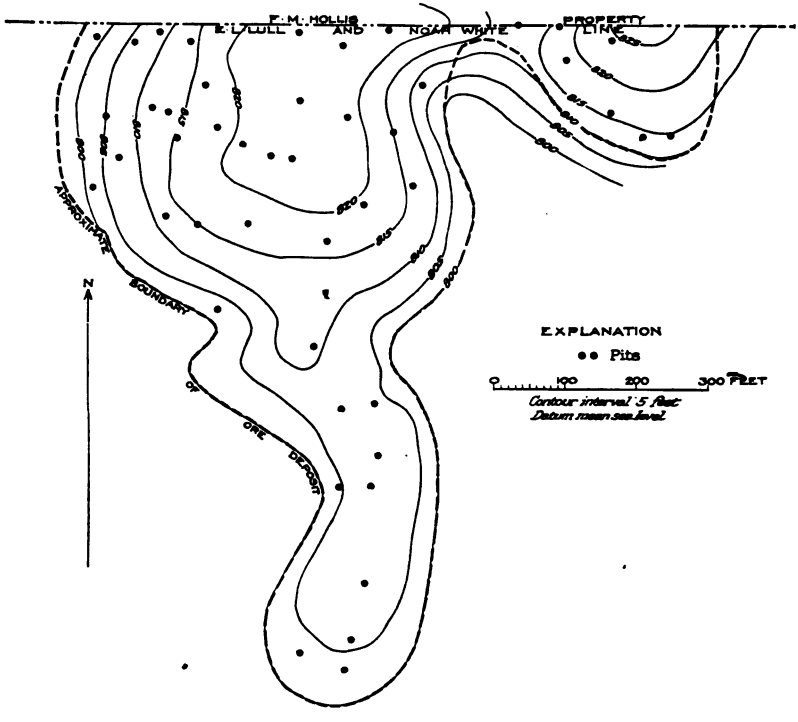


FIGURE 5.—Map showing location of pits at the Lull-White prospect and showing the approximate boundary of the iron-ore deposit. Drawn from map by E. L. Lull.

Unnamed prospect (79)

An iron-ore-bearing tract owned by a corporation at Scranton, Pa., is on the crest of a hill half a mile northeast of the mouth of Stults Branch, 2 miles southwest of Hardwick and 3 miles northwest of Iron City. In 1915 it was prospected by E. L. Lull for A. J. McGary by means of pits which were put down over an area of 30 or more acres. It is said that the ore-bearing area included 5 or 6 acres and that the iron ore in this area contains too much sand to be salable under present conditions. The ore is brown iron oxide and occurs in red clay.

Lull-White prospect (80)

The Lull-White prospect which is owned by E. L. Lull and Noah White, is on the crest and west point of a spur, half a mile east of Butler Creek and 2½ miles west-northwest of Iron City. Many pits have been made at this locality, most of them having been made in 1912 or 1913. The accompanying map (Figure 5) which was prepared by E. L. Lull shows the location of the pits. The pits, all of which were visited by the writer, are mostly less than 6 feet deep, but a few are as much as 20 feet deep. They show the ore-bearing area to cover about 9 acres.

Most of the pits reveal ore in minable quantity. None of the deeper ones and only a few of the shallow ones failed to reveal ore.

The ore is brown iron oxide and consists of lump and shot ore free from sand except in one pit near the south edge of the deposit. It occurs in red clay which at places contains much chert. The excellent quality of the ore and the size of the ore deposit mean that the deposit can be successfully worked at some time in the future.

Hollis prospect (81)

The Hollis prospect, which is owned by F. M. Hollis, is 2½ miles west-northwest of Iron City and is just north of the Lull-White prospect. The iron ore deposit at the Lull-White prospect is continuous with that at the Hollis prospect but the ore-bearing area at the Hollis prospect does not exceed one acre in extent. The character and the occurrence of the ore are the same as those of the ore at the prospect to the south. Although the ore is of good quality the quantity of it would probably not justify mining except in connection with the mining of the ore at the Lull-White prospect.

Stults prospect (82)

A reported occurrence of iron ore, not visited by the writer, is on the Stults property on the crest of a ridge, 1 mile northwest of the Lull flint mine on Butler Creek and 3½ miles west of Iron City. It has been prospected to a small extent for iron ore. The mineral right of the property is owned by a corporation at Scranton, Pa.

Van Leer mine (83)

The Van Leer mine, also known as the Gray mine, is on the crest of the ridge between Holly and Butler creeks, 1½ miles west-northwest of Iron City. It is on one of several adjoining tracts from which about 40,000 tons of iron ore was mined by Sam Van Leer between 1832 and 1837. Most of this production, however, came from the Van Leer mine. The lump ore was separated by Mr. Van Leer from the clay by hand-picking. It was then placed on stacks of wood which were burned, and was next hauled in wagons to the Van Leer Furnace, a charcoal furnace, operated by water power, 1½ miles southwest of the mine. (See Plate III, B). The mine was owned for a number of years by the Sheffield Coal & Iron Co. and was sold in 1918 by this company to J. J. Gray, jr., of Rockdale, Tenn., for whom the property has been operated by Dr. L. J. Gray, beginning in November, 1919. It was being operated at the time of visit (April 6, 1920) by means of a steam shovel and the area of the cut at that time was 2½ acres and the depth was 12 to 18 feet. The cut and the old and new prospect holes adjoining the cut show that the ore-bearing area comprises about 17 acres and that the ore extends at places to a depth of as much as 40 feet. Also pits in the floor of the cut show the ore to extend 8 or 9 feet deeper.

The iron ore is brown iron oxide in small and large masses which are disseminated through red clay from the surface down to the depths just indicated. The clay at places is barren of ore and such is dumped by the track and is not taken to the washing plant. The ore-bearing clay contains chert fragments and boulders particularly in the deeper parts of the openings but much of it near the surface is free from chert so that it is left for later and deeper mining when chert will be encoutered. The reason for this is that the chert-free clay will not disintegrate readily in the washing plant. The ore that was observed on the northeast side of the property is very sandy in places and some of it is porous. Chert fragments at some places are cemented together with iron oxide. The largest of these masses and the largest chert boulders are discarded in the cut. The presence of a pink mineral in one of these discarded masses was called to the writer's attention by Dr. Gray and specimens of rock containing it were collected and submitted to W. T. Schaller of the U. S. Geological Survey, who reports that the pink mineral is strengite, an iron phosphate. He also discovered beraunite, a reddish-brown iron phosphate, and cacoxenite, a fibrous canary-colored iron phosphate. This locality is one of the four occurrences of strengite in the United States known to the writer.

The production of the Van Leer mine from December, 1919 to March, 1920, was 8,445 tons of washed ore and to yield this 21,870 cubic yards of ore-bearing clay were treated. This means about .4 ton of washed ore for every cubic yard of ore-bearing clay.

The ore-bearing clay is conveyed on a narrow-gauge tram road from the mine to the washing plant where it is freed from the clay and chert fragments. The plant is equipped with two 20-foot steel logs and one set of jigs with four compartments, and has an average capacity of 5,000 tons of washed ore per month. Water for the plant is obtained from Shoal Creek at Iron City, from which the lift is 240 feet. The ore is loaded from the ore bins into freight cars which are brought to the plant on a branch line from Iron City about 1¼ miles long. A part of the marketed ore is purchased by the Sheffield Iron Corporation and is thus shipped to Sheffield, Ala., where it is used in making pig iron; the rest of the ore is shipped to the furnace of J. J. Gray, jr., at Rockdale, Tenn., where it is mixed with phosphate rock for use in making ferrophosphorus.

Seavy-Lull mine (84)

The Seavy-Lull mine, owned by the Southern Tennessee Development & Mining Company, is on the crest of the ridge between Butler and Holly creeks, 1½ miles west-northwest of Iron City and is just south of the Van Leer or Gray mine. It is on one of the several adjoining tracts that were worked by Sam Van Leer between 1832 and 1837 and the pits made at that time are still visible. The ore that was mined consisted

entirely of lump or boulder ore and was hauled in wagons to Van Leer Furnace 1½ miles southwest of the mine where it was smelted into pig iron. The tract was extensively prospected by means of pits by the Southern Tennessee Development & Mining Co. several years ago and mining was begun late in 1919 by J. J. Gray, jr., to whom the tract was leased. Mining was done by a steam shovel by Mr. Gray for only a short time when bad weather necessitated discontinuance, and it was idle at the time of visit (April 6, 1920). The production by Mr. Gray

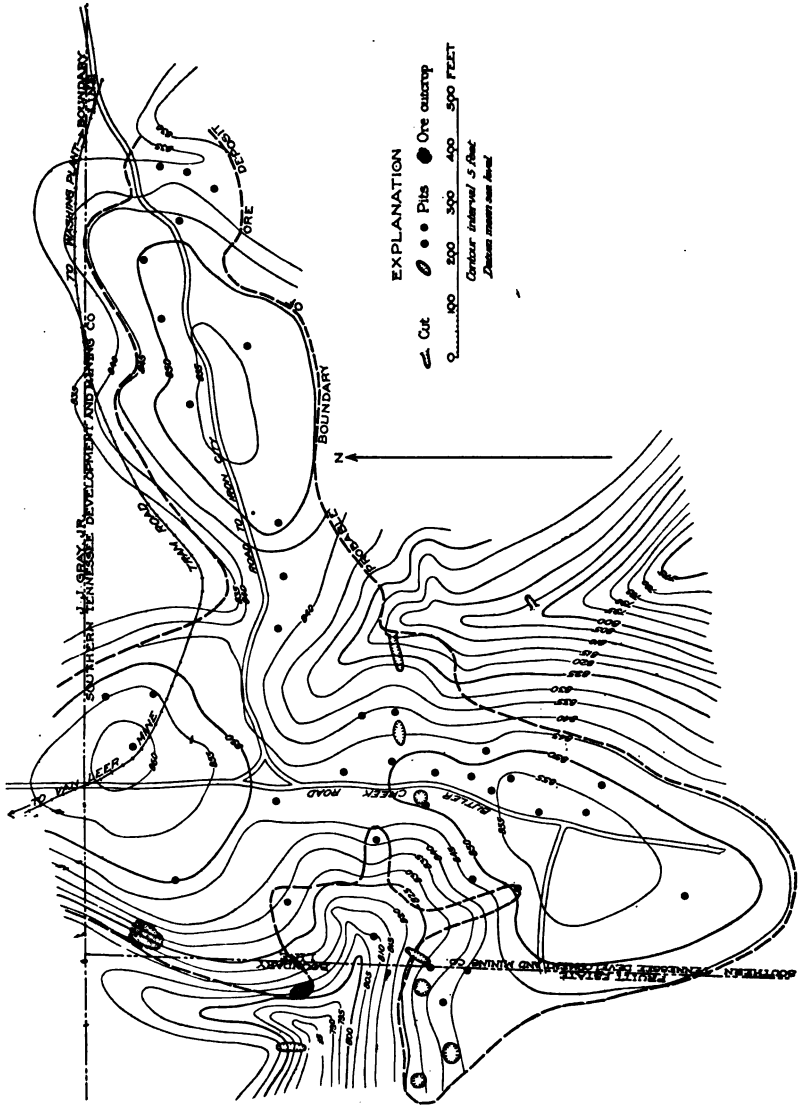


FIGURE 6.—Map showing the probably boundary of the ore deposits at the Seavy-Lull and Pruitt mines which are on the property of the Southern Tennessee Development & Mining Co. and on the Pruitt estate, respectively. Drawn from map by E. L. Lull.

before that time was 714 tons of washed ore. The operation of the mine is to be resumed later.

The small steam shovel cut about 200 feet long, 8 feet deep and less than 100 feet wide, and numerous pits and ore outcrops show the ore-bearing area to comprise approximately 20 acres, and some of the deeper pits show ore to a depth of 30 feet. (See Figure 6). Practically all of the openings were visited and very few were seen that did not contain ore.

The ore is brown iron oxide, and consists of both massive, lump, and shot ore. The finer particles of ore occur in red clay on the crest of the ridge to a depth of 6 to 10 feet. This thickness of clay is so free from chert fragments that clay balls are formed in the log washer and are disintegrated with difficulty. The more massive ores extend from 6 or 10 feet to as much as 30 feet below the crest of the ridge. They occur in cherty clay in which the amount of chert increases with depth. The massive ore crops out at places on the hillslopes. Some of it contains chert fragments, but it and the lump and shot ores are comparatively free from sand. The following are analyses of samples from the recent prospect pits:

Analyses of iron ore from the Seavy-Lull mine

	1	2	3	4	5
Iron (Fe)	49.76	54.35	54.22	54.55	54.02
Manganese (Mn)	.....	.48	1.08	.51	.....
Phosphorus (P)	.74	.98	.92	.64	1.07
Sulphur (S)	.....	.....	.....	.....	.014
Insoluble residue	10.00	6.30	4.90	7.25	.....
Silica (SiO_2)	.....	.....	.....	.....	6.98
Magnesium carbonate ($MgCO_3$)	.41	.....	.....	.....	.....

Analyses 1-4 from Purdue, A. H., The iron industry of Lawrence and Wayne counties: The Resources of Tennessee, vol. 10, p. 384, 1912; Samples collected by Paul Seavy of Iron City; analyses by the Sloss-Sheffield Steel & Iron Co.

Analysis 5 of samples collected by N. F. Drake; analysis by Paul C. Bowers.

Bromly mine (85)

The Bromly mine owned by the Bromly heirs is on the crest of the ridge between Butler and Holly creeks, 1½ miles west-northwest of Iron City and is just north of the Van Leer or Gray mine. The ore body adjoins that of the Van Leer mine. It is on a part of the tract that was worked by Sam Van Leer from 1832 to 1837 and several pits as much as 22 feet deep have been made since then. The old and new openings and surface showings of ore indicate that the ore-bearing area probably comprises between 6 and 7 acres, and extends to a depth of as much as 22 feet. (See Figure 7).

The ore is brown iron oxide and is similar to that at the Van Leer mine. The ore body is apparently of workable size.

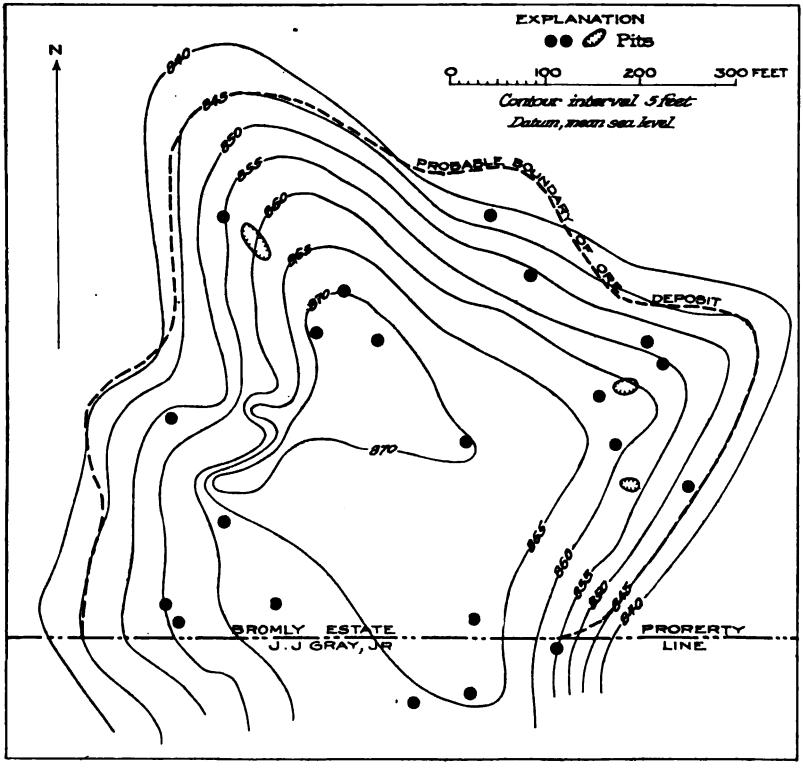


FIGURE 7.—Map showing the probable boundary of the ore deposit at the Bromly mine on the Bromly estate. Drawn from map by E. L. Lull.

Pruitt mine (86)

Pruitt mine belonging to the Pruitt heirs adjoins the Van Leer mine on the north and Seavy-Lull mine on the east. Iron ore was mined at this locality between 1832 and 1837 by Sam Van Leer and was hauled to the Van Leer Furnace on Butler Creek. Only 2 or 3 pits have been made in recent years. The ore is brown iron oxide and consists of wash, lump, and massive ores like those at the two adjoining mines. Although they are of good quality the ore-bearing area does not exceed a few acres and is therefore probably too small for it to be worked profitably except in connection with the mining of the deposits at the adjoining mines. (See Figure 6).

Powell mine (87)

The Powell mine, owned by the Sheffield Iron Corporation, is on the crest of a hill 1½ miles southeast of Wayland Springs and 2½ miles northeast of Iron City. It was operated many years ago by Smith & Sharp by means of picks and shovels, and the ore was conveyed by means of a tram line to a small washing plant.

The workings consist of two cuts. The larger of these comprises an area of 6 or 7 acres, follows the crest of a ridge with a southeastward trend and is 15 feet deep at the deepest place. The other cut comprises about 1 acre, does not exceed a few feet in depth, and is just west of the northwest end of the large cut.

The ore is brown oxide and consists mostly of shot and lump ore; at places there is some massive ore. It is free from sand and chert fragments, and is hard and compact though the massive ore and some of the lump ore are porous. Many fragments contain large cavities surrounded by a shell of iron oxide as much as 1 inch thick and have been given the name bomb shell ore. The ore is disseminated more or less uniformly through red clay in which there is at places a small quantity of chert. The occurrence of ore in the bottoms and sides of the cuts and on the surface on the crest of the ridge for 350 feet southeast of the larger cut indicate that much ore remains to be mined. Deeper mining will however encounter a larger amount of chert associated with the clay and ore than was found at and near the surface.

Allen prospect (88)

The Allen prospect belonging to the Southern Tennessee Development & Mining Co. is on the crest of a hill 1½ miles northeast of Iron City and about a half a mile north of the Columbia, Florence and Sheffield Branch of the Louisville & Nashville Railroad. Thirty pits which were made several years ago were dug in ore-bearing clay to a depth of as much as 10 feet. These and the presence of iron ore on the surface show that such clay covers an area of between 2 and 3 acres over which it will probably average 4 feet in thickness. The ore is brown iron oxide and consists of compact hard shot and lump ore free from sand. Although the deposit is of small size it can probably be worked because of the apparent good quality of the ore and the nearness of the deposit to the railroad.

Holt prospect (90)

The Holt prospect is on the east side of Cypress Creek 2½ miles north of Cypress Inn. Several pits as much as 30 feet deep have been made in a nearly level field in the valley of a small stream that runs west into Cypress Creek and have been made on a bench to the south that stands 50 to 75 feet above the field.

Brown iron ore apparently of good quality was found in all of the openings. It occurs as pockets and veins in clay and chert that have been derived from the St. Louis limestone and probably half of the ore-bearing material is ore. The accompanying analysis represents the composition of a sample which was collected by N. F. Drake. Much of the ore is free from chert but most of it contains chert fragments and many of the fragments have been largely replaced by iron oxide.

Analysis of iron ore from the Holt prospect

(Paul C. Bowers, analyst).

Iron (Fe)	55.44
Phosphorus (P)	.987
Sulphur (S)	.005
Silica (SiO_2)	6.11

The deposit at this locality apparently occurs over an area of at least several acres and it may be worked successfully at some time in the future if a railroad is built near it. The concentration of the ore would require a washing plant equipped with a crusher and jigs. A small perennial branch drains the valley in which some of the openings occur but would probably not furnish sufficient water for a washing plant. Cypress Creek would however furnish sufficient water through the entire year.

Prospect near Cypress Inn (91)

An iron-ore prospect which is on the property of the Tennessee Charcoal Iron Co. is on the east side of Cypress Creek and 1½ miles north of Cypress Inn. A few small pits have been made at the base of the hill and east of the road. The iron ore revealed in them and in natural outcrops for a distance of 500 feet along the hillslope occurs in large masses as much as 15 feet thick vertically. It is hard and compact and is free from sand but some of it contains chert fragments and pebbles. An analysis of a sample collected by N. F. Drake is given below. The deposit is in clay and chert that are residual from the St. Louis limestone and these are overlain by more than 50 feet of the Tuscaloosa gravel.

Analysis of iron ore from prospect near Cypress Inn

(Paul C. Bowers, analyst).

Iron (Fe)	55.44
Phosphorus (P)	.508
Sulphur (S)	.012
Silica (SiO_2)	6.17

Further prospecting may prove that the ore body is of considerable size and if so it may be of value if a railroad is ever constructed to pass near this locality. The ore body will probably be found to extend into the hill underneath the Tuscaloosa gravel and if extensive mining is done underground mining will be required on account of the great thickness of gravel.

Other occurrences near Cypress Inn

Brown iron oxide is exposed at the south base of a hill by the side of the road half a mile south of Cypress Inn and just north of the Alabama-Tennessee line. The quantity of the oxide thus exposed is small but it is apparently of good quality being hard, compact, and free from sand. It occurs in clay and chert that have been derived from the St. Louis limestone and some of it cements chert fragments together. The Tuscaloosa gravel caps the hill and is 50 feet or more thick. If

any prospecting is done here it should be confined to the clay and chert at and near the base of the hill, because minable iron ore is nowhere known to occur in the Tuscaloosa gravel. If such prospecting should reveal a workable ore body underground mining would probably be necessary on account of the great thickness of gravel above the chert and clay.

Iron oxide occurs in the bed of a small stream southeast of the above-described locality and also on the hillslopes southeast of the stream where it forms the cementing material of a gravel conglomerate.

Other occurrences of iron ore

Exposures of iron oxide were observed along the wagon road from Flatwoods eastward for about 1 mile. It cements together chert fragments and occurs as loose masses on the surface and as veins and pockets in the Fort Payne chert and in chert that has been derived from the St. Louis limestone. Veins of such iron oxide, 1½ inches thick, were observed in the lower part of the Fort Payne chert near Bells Ford on Buffalo River.

Iron oxide forms a cementing material in the Tuscaloosa gravel at numerous places and the gravel thus cemented together has become a hard conglomerate. Such conglomerates are especially abundant at or near the base of the Tuscaloosa gravel. They are very resistant and form projecting ledges. One such ledge near Stout in the southwest corner of the quadrangle is 30 feet thick and forms a bluff of that height.

Very small particles of iron oxides occur on the surface at numerous places on the crests of the ridges in the east half of the quadrangle. They are sufficiently numerous at some places as at the head of Couch Branch and near Dogwood Mudhole to give a brown color to the soil. They are generally associated with gravel which is present on most of the ridges in this part of the quadrangle. The gravel is, however, not thick enough or widespread enough at most places to be represented on the accompanying map (Plate I, in pocket).

DEPOSITS ASSOCIATED WITH ROCKS OF DEVONIAN AGE

Several deposits of iron ore that are residual from rocks of Devonian age occur in the northwest part of the Waynesboro quadrangle and some are beyond its borders. Those that are in the quadrangle are described below.

Sanders mine (92)

The Sanders mine is on a low round hill one-fourth mile southwest of the toll-gate on the Clifton-Waynesboro pike and 1½ miles south-southeast of Clifton. It is on the Narcis Sanders estate of which Mollie M. Claiborne of Nashville, Tenn., is executor. It was worked before the Civil War and the iron ore from it was taken to Marion Furnace

which was located near the Hughes Hollow Spring 2 miles south of Clifton. In 1910 or 1911 the Atlas Paint Co. of Nashville, Tenn., mined some of the red ocherous clay in which the iron ore occurs, treated it and sold it as ochre; but mining was soon discontinued; the reported reason for its discontinuance is that the color of ochre was not satisfactory as it differed from that of most red ochres from other localities. The crude clay was sacked at the mine, then hauled to Clifton where it was placed on barges which were taken down Tennessee River to Johnsonville on the Nashville, Chattanooga & St. Louis Railway, and from Johnsonville it was shipped to Nashville where it was treated.

The mine openings which are trenches and pits 10 feet or more deep were made on the crest and slopes of the hill. Their sides had caved in before the time of last visit (April, 1920) and the hill though once cleared of timber, is now largely covered with a dense almost impenetrable thicket of young pine trees.

Fragments of iron ore from a fraction of a pound to several pounds in weight occur in a dark red sticky clay not only in the openings but also on the surface over an area of several acres. Many of the fragments are irregular in shape; others are hollow and thus resemble bombshells; and others are small, flat slabs. They are hard, are generally compact, and consist of both brown and red oxides of iron. Many of them contain casts of fossils, suggesting that the fragments are residual from limestone. C. O. Dunbar[1] who has made an extensive study of the Devonian rocks of western Tennessee concludes that the iron ore at this locality is residual from the Bear Branch limestone member of the Olive Hill formation. This member is not exposed at this locality, but according to Dunbar it crops out at several places between Clifton and Olive Hill which is 9 miles south-southwest of Clifton. He describes it as consisting of impure coarse-grained limestone and oolitic hematite. He says, "The iron is a primary deposit, having accumulated along with the limestone, and its character is the same as that of the well-known Clinton iron ore." The presence of fossil brachiopods of large size in the fragments of ore suggests that parts of the limestone have been replaced by secondary enrichment during the process of weathering.

The ore, as is indicated by the accompanying analysis of a specimen collected by N. F. Drake, is of good quality. From surface outcrops and from exposures made in mining it appears that the ore body is 10 feet or more thick over an area of several acres and that the ore may occur in sufficient quantity to justify mining. One old shaft is reported to have penetrated the ore-bearing clay to a depth of 25 feet, without passing through it. Further prospecting will, however, be required to determine the quantity of available ore.

[1]Dunbar, C. O., Stratigraphy and correlation of the Devonian of western Tennessee: Tenn., Geol. Survey Bull. 21, pp. 20-21, 44-45, 1919.

Analysis of iron ore from the Sanders bank

(Paul C. Bowers, analyst.)

Iron (Fe)	57.66
Phosphorus (P)	.272
Sulphur (S)	.01
Silica (SiO_2)	5.44

Other occurrences of iron ore

Masses of brown iron ore, usually of small size crop out on the hillslopes just below the Hardin sandstone in Hughes Hollow, 2 miles south of Clifton; on the hill east of Peters Landing; on a hillslope 2¼ miles south-southeast of Peters Landing; and at a locality 1 mile south-southeast of the Sanders mine. At the last-named locality such ore was mined to some extent before the Civil War and is said to have made excellent grade of iron. This ore was probably hauled to either Marion Furnace or to the furnace at Furnace Landing, 1 mile west of Clifton.

The brown iron ores that were used many years ago in the two furnaces at Bob Landing about 6 miles northwest of Clifton and in the Brownsport Furnace 10 miles north-northwest of Clifton and 6 miles southeast of Decaturville are said to have been obtained from the same horizon as that of the above-mentioned deposits.

Whether a part or all of these ores, has been derived from the Bear Branch limestone or has been formed by downward concentration from other sources, such as the Chattanooga and Ridgetop shales, is not known.

DEPOSITS IN THE BRASSFIELD LIMESTONE

The Brassfield limestone, like red iron ore in the "Rockwood" formation of East Tennessee, forms a part of the Silurian system and it and the "Rockwood" are of nearly the same age, though the Brassfield is a little older than the "Rockwood."

The Brassfield limestone ranges in thickness from 1 to 25 feet and crops out at a great many places in the Waynesboro quadrangle. It is generally gray and free from iron oxides but in Cedar Point near Iron City, it is brown from the presence of disseminated iron oxides and contains 17 per cent of metallic iron. It has been mined at that place and has been used as a flux with the brown iron ores from Pinkney. To such limestone the local trade name spathite has been given. Besides Cedar Point two other occurrences of spathite are known. These are in wells on the west side of Nolly Creek west of Cedar Point. There the spathite was found to be 3 feet thick and Mr. E. L. Lull says that an analysis of a sample showed it to contain 30 per cent of iron.

The Cedar Point mine owned by the Southern Tennessee Development & Mining Company is at the base of Cedar Point, which is a narrow ridge between Holly and Shoal Creeks just north of the junction of the two streams and is one-fourth mile north of Iron City. It was worked on both sides of the ridge from near the south end northward

A

B

(A) Section in the Lull flint mine, 2½ miles west of Iron City, showing the occurrence of two flint layers in shale in the lower part of the Fort Payne chert. The man is standing on the lower layer and is resting his hand on the upper layer.

(B) Iron ore ("spathite") in the Brassfield limestone at the Cedar Point mine, ¼ mile north of Iron City. The point of the hammer is at the contact between the spathite and the Osgood limestone and the camera case is at the contact of the spathite with the Fernvale formation.

for several hundred feet, the work having been done from 1896 to 1900, and during this time 10,000 tons of ore was mined and shipped.

The openings are tunnels which have been made at the base of a bluff and just above the level of the Pinkney branch of the Louisville and Nashville Railroad. One of the tunnels extends through the ridge.

The ore which is, as previously stated, known as spathite is a bed of iron-bearing limestone which lies in a nearly horizontal position, though the tunnel that extends through the ridge shows that the spathite lies in a very shallow syncline. It is exposed along the base of the bluff on the east side of the ridge for a distance of about 2,000 feet northward from the south point of the ridge. How much farther it extends to the north beneath cover is not known. Where exposed it ranges in thickness from a few inches to 4 feet, but the usual thickness is 2½ to 4 feet. (See Plate XI, B). The spathite is a brown, crossbedded, medium-grained limestone with a few fossils. Its upper part contains a small amount of gypsum in thin layers and small pockets of white barite, and at places is somewhat siliceous from silica which has apparently replaced the limestone. The average iron content of the marketed ore is said to have been about 17 per cent. A partial analysis of a sample of the spathite collected by Dr. N. F. Drake follows:

Analysis of spathite from the Cedar Point mine
(Paul C. Bowers, analyst.)

Iron (Fe)	16.48
Phosphorus (P)	.456
Sulphur (S)	.116
Silica (SiO_2)	9.87

The iron is present for the most part in the form of a brown oxide which is more or less uniformly disseminated as minute particles through the bed; a small part of it may occur as siderite. Some of the fresher portions of the bed contain grains of glauconite and it is overlain at places by a layer of pebbly glauconitic limestone as much as one inch thick. The presence of the glauconite in the bed indicates that the bed is the Brassfield limestone. The bulk of this limestone at practically all other places in the quadrangle contains glauconite more or less uniformly disseminated through it. This and the occurrence of glauconite in the fresher parts of the ore bed suggest that the iron oxide of the ore bed originated from this mineral, but if so it is necessary to assume that there was an original large concentration of glauconite at this locality or that there has been lateral concentration of the iron because the usual quantity of glauconite in the limestone at other places does not exceed a few per cent and is therefore too small for the limestone to contain 17 per cent of iron.

A. H. Purdue[1] made the following statement regarding the origin of the iron:

[1]Purdue, A. H., The iron industry of Lawrence and Wayne Counties; The Resources of Tennessee, Tenn., Geol. Survey, vol. 2, p. 388, 1912.

"The synclinal structure of the ridge and the impervious character of the rocks overlying and underlying the ore bed strongly suggest that the iron had its origin in the bed itself, having been dissolved out from the two sides of the syncline and concentrated along the axis or lower part of the troughlike structure, by ground-water."

The spathite is underlain by green shale and limestone in thin layers which form the upper part of the Fernvale formation and is overlain by 48 feet of limestone and shaly limestone of the Wayne formation, 2 feet of the Hardin sandstone and 22 feet of the Fort Payne chert. (See Plate XI, B).

The marketed ore from this mine was shipped to Florence, Ala., and was used as a flux with brown iron ore from Pinkney. There is much ore still available at this place, and although it is of a low grade, the demand for fluxing material, and the favorable location of the deposit, both for mining and shipping, may again make it profitable to mine.

MANGANESE ORE

ECONOMIC FEATURES

Manganese ore has been prospected for at a number of places in the Waynesboro quadrangle. It was first prospected for about 1880 at a locality on the T. S. Hassell property 3¼ miles west-northwest of Waynesboro and in recent years during the World War when there was a great demand for domestic manganese ores for which high prices were paid work has been done at this and at other places. Two carloads of low grade ore were shipped from the Wade-Reynolds prospect 1 mile southwest of Hardwick but it was not used on account of the high silica content. Also a carload of ore was marketed from the T. S. Hassell property; this was shipped to the Tennessee Coal, Iron & Railroad Co. at Birmingham, Ala.

The manganese deposits are of small size and the ore contains a high percentage of silica whose separation from the ore would require treatment in a concentrating plant. The writer's opinion is that no manganese ore in the quadrangle can be mined and marketed with a profit whenever normal prices are paid for manganese ores and that only a small quantity of ore can be mined and marketed with a profit during times of high prices such as those that were paid during the World War. There may, however, be discovered small deposits of manganiferous iron ore that may be of commercial importance.

Descriptions of the known deposits including their geologic features are given below.

Hassell Prospect

The Hassell prospect, which is on the property of T. S. Hassell of Clifton, is 3¼ miles west-northwest of Waynesboro. The first work was done here in 1880 or soon thereafter by G. W. Boyd for Col. G. W.

Boyd and for a Mr. McClanahan, but no manganese ore was shipped. The next work was done in 1918 by H. D. Cooper who mined and shipped one car of manganese ore. The ore that was shipped by him was hauled in wagons to Collinwood, a distance of 15 miles, which was the shipping point.

The prospect consists of several cuts which have been made at and near the base of the hill slopes on either side of a narrow north-south hollow and tributary hollows for a north-south distance of about one-fourth mile. These hollows are drained to the south into Parker Branch which runs into Hardin Creek.

The cut that is farthest north is 25 feet long and has a face of 12 to 15 feet. It reveals soft yellow platy chert in which there is a zone, 1 to 2 feet wide, of branching veins of iron and manganese oxides with a high dip to the south. The oxides are intermixed (see Plate XII, A) but those of iron predominate on the hanging wall side of the zone and those of manganese predominate on the foot wall side.

Another cut, with a length of 35 feet and a face of 15 feet, which is in the north-south hollow, and a third cut, with a length of 60 feet and a face of 18 to 20 feet, which is in a tributary hollow from the west, reveal gray, hard, massive, much fractured chert in their upper parts and soft cream-colored and pink chert in their lower parts. Oxides of iron and manganese cement together fragments of the hard massive chert and occur as veins 3 feet or less wide in the soft chert, but those of iron are most abundant in the upper parts of the cuts and those of manganese are most abundant in the lower parts.

The chert thus revealed in these and also the smaller openings lies in a horizontal position and forms a part of the top of the Fort Payne chert or is residual from the lowermost beds of the St. Louis limestone. The oxides under discussion occur in it at approximately the same elevation in all of the openings and thus occur at about the same geologic horizon. They have not only penetrated small cracks in the massive fractured chert described above but have replaced parts of the chert fragments as is shown by the irregular borders of the areas of chert that occur in the masses of oxides. Furthermore the oxides have replaced the porous chert as is shown by the irregular boundaries that separate the chert from the oxides. (See Plate XII). Analyses of specimens of the iron and manganese oxides from this prospect are said by Mr. Boyd to show that the percentage of manganese ranges from 15 to 40 and that the percentage of iron is as much as 36. The fragments of them that have been removed from the openings not only contain chert fragments but much chert adheres to their surfaces. The ore that was marketed by Mr. Cooper was placed on ricks of wood which were then burned in order to free the ore from the chert so far as possible. The writer saw considerable ore that had been subjected to this treatment and although the silica content had been reduced by this process it was still high. It

appears to the writer that a marketable ore can be obtained only by handpicking combined with treatment in a concentrating plant that is equipped with a crusher and jigs. The deposit is probably too small and the cost of the mining and concentration of the ore would probably to be too great for the deposit to be worked under normal conditions.

Helton Prospect

The Helton prospect which is on a tract owned by W. M. Helton is on the north end of a ridge south of Hardin Creek and 5½ miles southwest of Waynesboro. A few small pits were made in 1918 by G. W. Boyd on the crest of the ridge at an elevation of 235 feet above Hardin Creek.

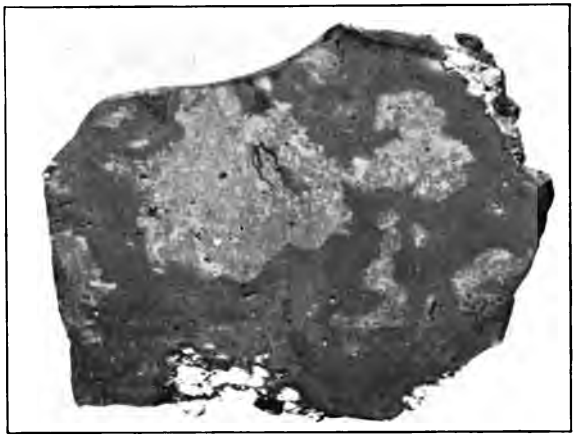
A soft yellow porous chert most of which falls to a fine powder when struck with a hammer is revealed in the pits; it lies nearly horizontal and is in the upper part of the Fort Payne chert. The largest pit, which is 7 feet deep, 15 feet long, and 10 feet wide, reveals veins and masses of psilomelane, wad, and brown iron oxide, which are generally intermixed. The minerals were not deposited in fissures but as shown by the irregular outlines of chert in them they have replaced parts of the chert. The veins and masses do not exceed a few inches thick; some of them are parallel with the bedding of the chert but others cut across the bedding. The manganese minerals are said by Mr. Boyd to be most abundant in the bottom of the pit but those that occur there could not be seen at the time of visit (April, 1920) on account of the partial caving of the pit. The other pits show a much smaller quantity of iron and manganese oxides than the one just described.

Analyses of specimens of the brown iron oxide are said by Mr. Boyd to show that they contained 36 per cent of iron and analyses of specimens of the manganese minerals are said by him to show that they contained 15 to 40 per cent of manganese.

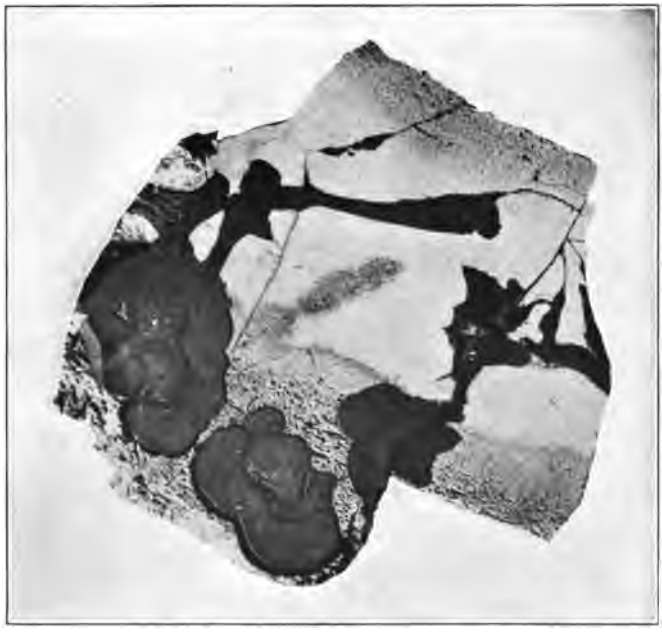
It is not likely that further prospecting will show manganese ore to exist in minable quantity but if so the silica content of the ore would probably be 15 per cent or more, and its iron content would also probably be high.

Arnett Prospect

The Arnett prospect which is on the T. J. Arnett estate is 1 mile south of Hardin Creek and 6½ miles southwest of Waynesboro. It consists of several small pits which were made in 1918 by G. W. Boyd on the slopes of a northeastward-trending spur at an elevation of about 300 feet above Hardin Creek. The pits penetrated chert and clay which are residual from the St. Louis limestone and some of them revealed considerable brown iron ore. The ore according to analyses that Mr. Boyd had made show that it contains from 4 to 14 per cent of manganese. It may therefore be classed as manganiferous iron ore. It is hard,



(A) A polished specimen from the Hassell prospect, 3¼ miles west-northwest of Waynesboro, showing mixture of psilomelane (light-gray) and brown iron oxide (dark-gray) that have replaced fossiliferous chert (white). A fossil Bryozoan indicated in the specimen by a curved line of light-colored dots is preserved in the psilomelane. Natural size.



(B) A polished specimen from the Hassell prospect, 3¼ miles west-northwest of Waynesboro, illustrating the replacement of chert (white) by psilomelane (black and dark-gray.) The areas of psilomelane with curved outlines are in soft porous chert, whereas the areas with irregular outlines are in hard compact chert. Natural size.

free from sand, and is porous and thus includes some clay. The apparent good quality of the ore and the considerable amount of it at some of the pits would seem to be sufficient reasons for doing further prospecting to determine the size of the ore body.

Wade-Reynolds Prospect

A manganese prospect which is on property owned by Messrs. Wade and Reynolds is at the southwest base of a hill 1 mile southwest of Hardwick. Small openings have been made here in recent years, and although two carloads of low-grade ore were mined and shipped to the furnaces of J. J. Gray, jr., at Rockdale, Tenn., it was not used because it contained too much silica.

An oxide of manganese at this locality occurs as thin veins in compact hard layers of chert near the top of the Fort Payne chert and some of it is disseminated through the chert as replacement material. It is present through a thickness of 6 to 8 feet of chert, but the aggregate thickness of the chert layers that contain this oxide in greatest quantity is 2 feet. The accompanying analysis of a sample of the manganese-bearing chert collected by N. F. Drake shows that the silica content is too high and the manganese content is too low for the deposit to be of commercial importance.

Analysis of manganese-bearing chert from the Wade-Reynolds prospect

(Paul C. Bowers, analyst.)

Manganese (Mn)	6.62
Phosphorus (P)	.058
Silica (SiO_2)	49.49

Other Occurrences of Manganese Oxide

An exposure of wad occurs on the north side of the head of Indiana Creek 1½ miles west of McGlamery's Stand and 3 miles southwest of Collinwood. It is in a bank formed by a landslide on a south hillslope just north of the wagon road which runs down Indian Creek. The wad occurs as small irregular masses in red clay in which there are many fragments of chert. It has replaced parts of the clay and has cemented together many of the chert fragments. The clay and chert are residual from the St. Louis limestone. As the wad, clay, and chert are so intimately mixed it is not likely that the deposit will be of commercial importance even though prospecting should prove it to be of large size.

Pockets of wad measuring several feet across are found in the iron-ore-bearing clays at some of the iron mines. They were observed by the writer at the Robinson mine near Corning. Thus far no commercial use has been made of them and it is not likely that any will be made of them because of their small size and irregularity of occurrence.

CEMENT ROCK

An argillaceous limestone containing approximately 75 per cent of calcium carbonate and 20 per cent of clayey materials (silica, alumina, and iron oxide) would be the ideal material for use in the manufacture of Portland cement, as such rock would contain within itself in the proper proportion all the necessary ingredients. It would require the addition of no other material, but when burnt alone would give a good cement. The analysis of limestone from the Hermitage formation and the analyses of Portland cement mixtures given below show that this limestone approaches very closely in composition the ideal Portland cement material. The limestone might also be suitable for making natural cement.

Analyses of limestone from the Hermitage formation and of Portland cement mixtures

	1	2	3	4	5
Silica (SiO_2)	14.19	12.85	12.92	13.52	14.94
Alumina (Al_2O_3)	2.95	4.92	4.83	6.56	2.66
Ferrous oxide (FeO)	.38	.....	.....	.....	.....
Ferric oxide (Fe_2O_3)	.21	1.21	1.77	.....	1.10
Calcium carbonate ($CaCO_3$)	79.23	76.36	75.53	75.13	75.59
Magnesium carbonate ($MgCO_3$)	1.04	2.13	4.34	4.32	4.64

1. Limestone from Hermitage formation at Clifton, Tenn., Paul C. Bowers, analyst.

2-5. Analyses of Portland cement mixtures ready for burning as used at various large cement plants in the United States. Eckel, E. C., Portland cement materials and industry in the United States: U. S. Geol. Survey Bull. 522, p. 65, 1913.

The limestone from the Hermitage formation was used in the manufacture of cement at Clifton before the Civil War and also after the war, the plant closing in 1888. The limestone was obtained from the right bank of Tennessee River at the west edge of Clifton and was manufactured into hydraulic cement in a very small plant at that place. None of the shale interbedded with the limestone was used. The cement is said to have set slowly but is said to have given excellent results. A cistern in Clifton that was built with it has stood for 65 years without repairs.

The principal outcrops of the Hermitage are on Whiteoak Creek; on Beech Creek near Mooney; on Eagle Creek south-southeast of Clifton; and along the right bank of Tennessee River at Clifton, at and near Glenkirk, and north of Lego. Of these outcrops those on Tennessee River offer the most favorable locations for quarrying the limestone and for the manufacture and shipping of cement. The Hermitage as seen at these and other outcrops is as much as 80 feet thick and consists of argillaceous limestone layers 2 to 6 inches thick, alternating in a remarkably regular way with calcareous sandy shale layers of about the same thickness. (See Plate XIII, B). The limestone layers have smooth surfaces and are dark gray in color, fine-grained and compact.

(A) Road material pit in chert that is probably residual from the lower part of the St. Louis limestone, 1 ¼ miles west of St. Joseph.

(B) Exposure of the Hermitage formation on the right bank of Tennessee River west of the boat landing at Clifton.

They do not contain enough clay to make them weather easily, but break up or fracture rather easily.

The composition of the limestone in the Hermitage formation, the regularity of the limestone in the formation and the good shipping facilities offered at Clifton, Glenkirk, and Lego, where the formation is exposed, are favorable conditions for using this rock for the manufacture of cement, but other conditions, some of which are given below, must be considered. Shale constitutes about half of the Hermitage so that half of the material that would be quarried would be waste unless some use could be found for the shale. As the investment in a cement plant is heavy, it would not be wise to locate a plant, under ordinary circumstances with less than 20 years' supply of raw materials in sight.[1] A thousand-barrel plant should have at least 1,500,000 tons of natural cement rock on its properties. The item of fuel cost is important for in the average plant about 30 to 40 per cent of the total cost of cement will be chargeable to coal. In order to achieve an established position in the trade, a new cement plant should preferably have a local market area, within which it may sell practically on a non-competitive basis, and easy access to a larger though competitive market area.

LIMESTONE FOR LIME

Limestone for making lime has, so far as the writer knows, been quarried at only one place. This is at the west edge of Iron City where limestone from a bed in the Ridgetop shale has been quarried and burned into lime for local use. A description of the limestone at this locality and a description of a similar limestone in the Fort Payne chert near West Point are given below. There are, however, probably other localities where limestone pure enough for making lime may be obtained from limestone beds in the Ridgetop shale and Fort Payne chert. Such localities need be looked for only in the southeast part of the Waynesboro quadrangle, because it is only there that these formations contain limestone.

Other limestones which may be suitable for making lime are the Bob and Decatur limestones. All of the exposures of the Decatur are confined to the northwest and west parts of the quadrangle and most of the exposures of the Bob are confined to these parts of the quadrangle. No exposures of the Bob and Decatur limestones are near railroads but many are near Tennessee River. These limestones are therefore not available at present for making lime unless water transportation on Tennessee River be used. Considerable lime of a high quality is consumed in the plant of the Wayne Wood Products Co. at Collinwood, but it is shipped from outside the quadrangle.

[1]This and subsequent statements are taken from E. C. Eckel, Portland Cement Materials and Industry in the United States ; U. S. Geological Survey, Bull. 522, p. 66, 1913.

A lens of limestone just north of the Iron City Spring at the west edge of Iron City has been quarried at times for use in making a small amount of lime. It is exposed on a south hillslope and is about 600 feet long, and 30 feet thick at the thickest place which is just north of the spring. It is light gray and coarse-grained, contains a great many fossils, and occurs in green shale in the Ridgetop shale. The occurrence of the bed just north of a railroad spur that runs from Iron City to the iron-ore washing plant of J. J. Gray, jr., makes its location favorable for quarrying.

Excellent outcrops of thick beds of limestone in the Fort Payne chert occur in and above the bluff half a mile southwest of West Point. The Pinkney branch of the Louisville & Nashville Railroad runs along the base of the bluff, so that this locality is a favorable site for lime kilns. Some of the beds of limestone are perhaps pure enough for the manufacture of lime, but so far as the writer knows no analyses of them have been made. On account of the massiveness of the limestone and the weathered condition of it on the surface one or more day's work would be required by two or three men to obtain representative samples for analyses. A section describing the beds is given below:

Partial section of Fort Payne chert half a mile southwest of West Point

	Thickness in feet
Gray coarse-grained massive limestone in some of which there are layers and nodules of chert; outcrops are numerous on the gentle slope above the bluff	40
Gray coarse-grained massive limestone; exposed in top of bluff	26
Cherty limestone, chert, and green shale; exposure in lower part of bluff extends down to the railroad track	50

LIMESTONE FOR FLUX

Limestone for flux was formerly quarried in the quadrangle but at present it is not being quarried for this purpose. The three blast furnaces in the quadrangle, Anna Furnace at Collinwood and Mannie furnaces at Allens Creek are supplied with limestone flux from outside the quadrangle.

The limestone that was formerly quarried for this purpose was obtained from the Laurel, Lego and Bob limestones and from limestone in the Ridgetop shale. The Decatur limestone may also be suitable for this purpose. The Bob and Decatur limestones are, however, not available under present conditions, because there are no outcrops of them near railroads. All of the above-named limestones occur in thick layers; they crop out at the surface over fairly large areas so that there is

very little or no overburden in such areas; and their chemical composition perhaps varies considerably from place to place so that some localities may afford a better quality of limestone for this purpose than others. Analyses of some of these limestones are given on pages 19.

A ferruginous limestone containing 17 per cent of iron has been mined by means of underground workings from a bed of limestone 2½ to 4 feet thick in the Brassfield limestone in Cedar Point one-fourth mile north of Iron City, and it was used as a flux with brown iron ores from Pinkney, but on account of its high iron content it is regarded as an iron ore. It is described on page 19.

The limestone-flux quarries are described below.

For many years limestone flux for the two Mannie furnaces at Allens Creek was obtained from the Laurel and Lego limestones in several quarries near Riverside and between this place and the village of Allens Creek, but owing to impurities in these limestones their use was discontinued 10 years or more ago, and limestone has been shipped in recent years from Lyles, Tenn. The accompanying analysis of a sample collected by the writer from a quarry in the Laurel limestone one-fourth mile south of Riverside shows the undesirable impurities, silica and alumina, to be as low as in many of the limestones now used for flux.

Analysis of Laurel limestone from quarry ¼ mile south of Riverside

(R. K. Bailey of the U. S. Geological Survey, analyst.)

Silica (SiO_2)	1.32
Alumina and ferric oxide (R_2O_3)	.92
Lime (CaO)	49.64
Magnesia (MgO)	4.80
Carbon dioxide (CO_2)	43.90

Limestone for use as flux in Wayne Furnace was quarried from the Bob limestone at a locality on the west side of Fortyeight Creek half a mile north of the mouth of Furnace Branch. The old quarries may still be seen though fairly large trees have grown up in them. They are at the west edge of the stream flat of Fortyeight Creek. The outcrops reveal 9 feet of the limestone above the level of the flat and also reveal the Hardin sandstone, several feet thick, resting upon the limestone. The limestone is coarse-grained, massive, and fossiliferous and is light to dark gray in color. Some of the fossils on parts of the weathered surfaces are siliceous and they therefore suggest that the unweathered limestone may contain considerable silica.

Limestone for flux has been quarried from a 10-foot bed of limestone that caps Cedar Point, a narrow ridge one-fourth mile north of Iron City. This limestone is coarse grained and light gray and contains a small quantity of chert in the form of nodules. Although the chert is in small quantity it would make against the use of this limestone for either flux or lime. Furthermore, the quantity of limestone is not great as the width

of the ridge does not exceed 200 feet. This limestone occurs near the base of the Ridgetop shale, the greater part of which has been eroded from the crest of the ridge.

LIMESTONE FOR STRUCTURAL PURPOSES

Limestone for rubble-work has been quarried from the Laurel and Lego limestones for local use. These and the other limestones in the Waynesboro quadrangle are thin bedded and are suitable only for rubble-work, with the exception of the Bob limestone and some of the limestone beds in the Fort Payne chert and in the Ridgetop shale which are thick bedded and which might yield good architectural building stone.

The Laurel limestone has been quarried just south of the depot at Iron City for use in building bridge piers and abutments; both it and the Lego limestone have been quarried for structural purposes at the south end of Cedar Point one-fourth mile north of Iron City; and slabs of these limestones have been used at Clifton for making sidewalks. These limestones are exposed in many parts of the quadrangle and afford a good stone for local masonry work. Their layers have a uniform thickness, weather with smooth surfaces, and yield layers of many thicknesses up to 2 feet. Furthermore, they are favorably exposed for quarrying at many localities where there is very little or no overburden.

The St. Louis limestone where it is free from chert would make an excellent gray-colored building stone, as it has a fine even texture and is massive, but there are only a few localities in the quadrangle where the unweathered limestone is present. These are in the northeast, central, and southwest parts of the quadrangle. Elsewhere, the calcium carbonate of the limestone has been removed through solution, leaving clay and chert as residual products of the limestone.

The beds of limestone that are present in the Ridgetop shale and Fort Payne chert in the southeast part of the quadrangle have a pleasing light-gray color, are compact and most of them coarse grained. The parts of the beds that are free from chert would make a superior building stone.

The Decatur limestone which is exposed at a considerable number of localities in the northwest part of the quadrangle is compact, fine to coarse grained in texture, has a pleasing light-gray to bluish-gray color, and occurs in even-bedded layers ranging from several inches to 2½ feet in thickness. It would make an excellent building stone.

The Bob limestone is coarsely crystalline, and light gray, is free from cavities and breaks and is in layers many feet thick. It is widely exposed in the west-central and northwest parts of the quadrangle and offers an abundance of limestone that may prove to be a good architectural building stone.

The Brassfield limestone is crystalline and light gray and generally occurs in even-bedded layers 2 to 4 inches thick though at places the layers are thicker. It would afford a good building stone.

MILLSTONES

A quarry from which millstones were obtained many years ago is on the crest of the ridge that is between the headwaters of Jeter Branch and Ross Creek 4 miles east of Clifton. The millstones were obtained from a hard massive somewhat porous bed of chert 15 feet thick. This bed of chert and also the other beds that cap the ridge were once a part of the St. Louis limestone from which the calcium carbonate has been removed during the process of weathering.

Millstones have not been obtained from this locality in recent years and not enough is known concerning the chert to say whether it would afford millstones for use under present conditions.

TRIPOLI

GEOLOGIC AND ECONOMIC FEATURES

The material called tripoli in the trade in the United States is a white or yellowish, light, porous and generally purely siliceous rock which has resulted from the leaching of calcareous material from very siliceous limestones or highly calcareous cherts. Some tripoli from Missouri is and always has been produced primarily for use as an abrasive, but most of it is mined to be worked up into filter blocks of various shapes. The cuttings and waste from making filters are ground and prepared for abrasive and other uses. Tripoli from Illinois is used in paint, wood filler, metal polish, in soaps, in cleansers, for making glass, tile, and enamel, and for facing foundry molds.

Tripoli occurs at a great many places in the Waynesboro quadrangle where it is locally known as "chalk." It occurs in the base of the St. Louis limestone and in the top part of the Fort Payne chert, but is mostly in the Fort Payne chert. At least a part of the St. Louis limestone is siliceous, and the Fort Payne chert is, or was originally, calcareous. When the calcium carbonate of these parts of the two formations here named is removed during the processes of weathering a soft siliceous porous rock known as tripoli is left at some places. The calcium carbonate has in fact been largely removed from nearly all surface and near-surface occurrences of these formations. Originally certain parts of the Fort Payne chert might have been designated limestone, it was so highly calcareous, but such rock is exposed at comparatively few places. Tripoli does not everywhere result from the weathering of the Fort Payne chert and St. Louis limestone. It is in fact rather rare that tripoli results from the weathering of the St. Louis limestone, but the topmost beds of Fort Payne chert nearly everywhere except in the southeast part of the

quadrangle, weather to a spongy-looking chert, mixed with fine siliceous powder and clay, or else into a good grade of tripoli. A few of the tripoli deposits have been prospected to a small extent but no tripoli has been marketed. Some unsuccessful attempts have, however, been made to find a market for it as an abrasive. Its quantity is great and the quality appears to be good. If there should be an increased demand for tripoli in the future some of the deposits in the Waynesboro may then be worked. The softness of the tripoli would apparently prevent the use of any of it for filter blocks.

Most of the occurrences of tripoli that were observed during the field investigation for this report are described below.

Green River and Chalk Creek

Near Waynesboro the tripoli occurs along the sides of the valley of Green River and along the sides of the valleys that enter the valley of Green River; but from a point three miles south of Waynesboro southward to a point about 6 miles south of that town the bed underlies the entire valley of Chalk Creek. It has probably been derived both from beds in the lower part of the St. Louis limestone and in the upper part of the Fort Payne chert.

Numerous exposures of tripoli derived from the Fort Payne chert occur just southwest of Waynesboro in an eastward-trending hollow which is drained eastward by a small stream that enters Green River half a mile south of the courthouse. One exposure shows a thickness of 25 feet of tripoli without revealing its base and top. Much of the tripoli is pure white, fine grained, and free from chert nodules, although such nodules and small quantities of iron and manganese oxides are common. The iron oxide where present gives a cream color to the tripoli and the manganese oxide occurs at a few places as minute black particles disseminated through the white tripoli. An analysis of a sample of tripoli from this locality was made by Paul C. Bowers and showed it to contain 96.49 per cent of silica and a trace of manganese.

A well, 80 feet deep, which was dug on the west side of the valley of Green River 3½ miles south of Waynesboro, passed through 50 feet of chert gravel and fragments and then penetrated a bed of tripoli to a depth of 30 feet without reaching its base. Most of the tripoli is pure white and very fine grained and at places contains some chert nodules. A bed of yellow porous rock, 1 foot thick, which yields the water in the well was found in the bottom of the well and this is said to be underlain by white tripoli. The tripoli at this locality has been derived from siliceous beds in the lower part of the St. Louis limestone or from the upper part of the Fort Payne chert. An analysis of a sample of it was made by Paul C. Bowers and showed it to contain 98.15 per cent of silica.

Exposures of white fine grained tripoli are common along Chalk Creek from the above-described well southward for a distance of about 3 miles. They reveal only parts—usually not over 4 or 5 feet—of the bed, whose entire thickness is perhaps 25 feet or more.

Dry Branch

A deposit of tripoli near the top of the Fort Payne chert is exposed on the head of Dry Branch 1½ miles northwest of Collinwood. It was being prospected at the time of visit (November 18, 1913). At that time a bed of tripoli, 14 feet thick, was exposed at the base of the hill-slopes and in a pit in the stream bed. Further prospecting will probably show a greater thickness, as well as a considerable areal extent for the deposit. The tripoli is a very fine grained gritty material, practically free from hard seams of rock. On the surface it is stained with iron oxide to a cream or yellow color, but blasting back into the hill away from the weathered outcrop revealed white tripoli.

Davis Branch

A bed of tripoli, 6 to 12 feet thick, in the upper part of the Fort Payne chert is exposed along the wagon road at the head of Davis Branch which is a tributary of Indian Creek. Some of the tripoli is pure white but most of it is cream colored. Pieces of porous chert occur in all parts of the tripoli bed.

Lutts

An exposure of white tripoli, 25 feet or more thick, in which there are chert fragments, occurs on the hill east of Lutts.

Grass Creek

A great amount of tripoli which is derived from siliceous beds in the St. Louis limestone is exposed in the hollows at and near the head of Grass Creek. At some places the tripoli bed is overlain by a thin layer of iron oxide and it generally contains some nodules of chert. Much of the tripoli is pure white but parts of it are red and yellow in color.

A bed of white tripoli, about 40 feet thick, which was derived from the St. Louis limestone, is exposed in a gulch 1 mile northwest of Stout. Half of the bed is soft friable tripoli but the rest of it is chert and tough tripoli. An analysis of a sample of the tripoli was made by Paul C. Bowers and showed that it contains 98.21 per cent of silica.

FLINT LININGS FOR TUBE MILLS

HISTORY AND PRODUCTION

Before the World War flint linings for tube mills, which are dimension blocks cut from flint or other hard siliceous rock, were obtained almost wholly from Belgium, but during the war the supply from that source was cut off so that it became necessary to depend upon domestic materials of which very little had been used previously. Flint for such linings was quarried and marketed in 1915, 1916, 1917, and 1918 from several localities near Iron City and St. Joseph, Tenn., and in 1917 from Fort White, Fla.; and in 1917, 1918, and 1919 quartzite for this purpose was marketed from Jasper, Minn. The use of the flint from Tennessee was discontinued as soon as the importation of material from Belgium could be resumed after the war. If this well-established source is ever cut off again the Tennessee flint may once more be used.

The flint from Iron City and St. Joseph was obtained from the lower part of the Fort Payne chert. It was first discovered by E. L. Lull on the property of C. E. Roesch near Hardwick, from which three carloads were shipped by Mr. Lull. Flint of suitable quality was later discovered at a locality on Butler Creek 2½ miles west of Iron City and on the property of John McKinney 2 miles southwest of St. Joseph. Mining was then discontinued on the Roesch property and was begun at these two localities. The flint at the locality on Butler Creek was discovered by Mr. Lull in a stone fence built of flint blocks and subsequent prospecting led to the discovery of two flint layers which have been extensively quarried.

The principal shipper in the district was the American Flint Co., of which E. L. Lull was proprietor and general manager. He mined and marketed 784 short tons of flint valued at $15,680 in 1916; 2,000 short tons valued at $40,000 in 1917; and 1,335 short tons valued at $25,034 in 1918. The flint that was marketed by him was shaped at the mines into blocks 5 inches thick, 6 to 14 inches long, and 5 to 8 inches wide and then shipped to the stamp mills of the Calumet & Hecla Mining Co., the Copper Range Consolidated Mining Co., and the Winona Copper Co., all of which are located in the upper peninsula of Michigan. It was used by these companies as linings in tube mills in which copper ores were treated. It proved to be a satisfactory substitute for the Belgian stone which is known in the trade as "Silex" but the efficiency averaged only 60 per cent of that of the Belgian stone. The other shipper of flint blocks was John McKinney who quarried and marketed 5 to 6 carloads of such blocks for use in lining tube mills. The deposits that were worked by Messrs. Lull and McKinney are described below.

A

B

(A) Flint from the Lull flint mine on Butler Creek, 2½ miles west of Iron City, illustrating its conchoidal fracture and laminae along which there is some calcium carbonate. The height of the specimen represents the thickness of the layer of flint. One-half natural size.

(B) Arrowheads from Iron City that were made by the Indians from flint in the Fort Payne chert. One-half natural size.

The flint layers at these and other places furnished the Indians who inhabited this region a suitable material for making arrows and other stone implements. (See Plate XIV). Most of the rock chips that were discarded by the Indians as well as most of the arrowheads and other stone implements that are found in the region are flint of this variety and source.

Lull Mine

The Lull mine which is owned by the Pruitt heirs is on Butler Creek in the southeast corner of Wayne County 2½ miles west of Iron City. It was operated by the American Flint Co., beginning in 1916 and ending in 1918, and from it between 3,500 and 4,000 short tons of flint for tube mill linings was marketed.

The mine consists of 4 open cuts. The largest of these, comprising an area of 2¼ acres, is just east of Butler Creek and trends southward from the west point of a hill across the stream flat, a distance of about 1,000 feet. The flint occurs in two layers, 3 feet apart, which are interbedded with hard platy greenish-gray shale containing small geodes of white quartz. (See Plate XI, A). The layers dip to the southwest 2⅓ feet for every 100 feet of horizontal distance. The flint is hard, compact, and dark bluish gray and breaks with a conchoidal fracture. (See Plate XIV, A). The layers contain a few cavities that have been filled with white quartz and parts of them contain small disseminated grains of calcite. They have a rather uniform thickness, the lower one averaging about 7 inches thick, and the upper one ranging from 4 to 5 inches thick. The upper layer is cut by two sets of parallel joints a few inches apart but the lower one is comparatively free from joints. The occurrence of the joints facilitated quarrying and the occurrence of one set of joints at right angles to the other also facilitated the shaping of the flint blocks with rectangular sides. A soft, somewhat porous siliceous parting, a fraction of an inch thick, from which calcium carbonate has probably been leached, occurs at places in the middle of the upper layer; and lenticular partings of gray siliceous limestone, a fraction of an inch thick, also occur in the lower part of the layer. The partings are softer than the bulk of the flint layers so that blocks containing them would not wear down uniformly during their use in tube mills, but none of the partings are so thick or so extensive as to have caused the rejection of any considerable amount of material.

The lower layer was found by prospecting to be absent west of the cut and the upper layer was found to be absent in the west half of the cut; their absence there is due to their having been eroded by Butler Creek. They both extend eastward beneath the stream flat and perhaps underlie an area of 8 acres over which the overburden of shale and yellowish-red loam would not exceed 12 feet in thickness. The overburden of this character that was removed from above the upper layer in the main

cut was as much as 12 feet thick. Such an area, according to Mr. Lull, would contain between 10,000 and 15,000 tons of available flint.

Although the flint layers were not present west of the main cut the lower one was found in and beneath the creek bed to the southwest. After the creek was largely diverted to an old channel to the southwest by means of a dike that was built of waste from the main cut, the layer was quarried from the stream bed over an area of one-fourth acre. The layer was similar to that in the main cut, except that it was somewhat thinner, averaging 6 inches thick, and that it was cut by parallel joints in two sets, each at right angles to the other. The overburden here was mostly gravel which did not exceed a few feet in thickness.

Two small cuts, from which 100 tons of flint was marketed, are on the lower southwest slope of a hill about one-fourth mile east of the main cut. The flint that was quarried occurred in two horizontal layers, 5 to 8 inches thick and 2 feet apart, interbedded with hard greenish-gray shale. It is compact and dark bluish gray, breaks with a conchoidal fracture, and contains at places lenticular porous partings and quartz geodes, up to 2 inches in diameter, filled with calcite. Flint with such partings was discarded. Numerous fractures run partly through the layers but did not bar their use for tube mill linings.

The flint from all of the above-described openings was quarried in open cuts. It and much of the waste were handled in two-yard rotary dump cars which were pushed by hand and pulled by mules. The waste was mostly dumped in the worked-out portions of the cuts. The quarrying was done by blasting and both day and night shifts were employed. Three air drills were used in the quarries. Much of the flint was hauled in wagons to Iron City on the Louisville & Nashville Railroad, a distance by wagon road of 3 miles; the rest was hauled south to Pruitton on the same railroad, a distance of 3 miles by wagon road. From these places the flint was shipped to Michigan, where it was used in the milling of copper ores. The flint was trimmed by hand with hammers into blocks with rectangular faces and the shaping of the blocks into uniform sizes was attempted when mining was first begun, but it was soon found not be feasible. The marketed blocks, however, had as previously stated, a uniform thickness of about 5 inches; their length ranged from 6 to 14 inches and their width from 5 to 8 inches.

McKinney Mine

The McKinney mine is on the John McKinney place in southwestern Lawrence County 2 miles southwest of St. Joseph and 2½ miles east of Iron City. Mining at this place was done by E. L. Lull in 1916 who shipped 2 or 3 carloads of flint, and by John McKinney who shipped 5 to 6 carloads. The entire production consisted of blocks which were used for lining tube mills. Mining was done at different places on both the north and south sides of Wolf Creek for a distance of two-tenths of a

mile above the opening that is farthest west, but was mostly on the north side.

The marketed flint was obtained from three, nearly horizontal layers, interbedded with hard greenish-gray shale, in the lower part of the Fort Payne chert.

The lowest layer was quarried from the bed of Wolf Creek a short distance southwest of Mr. McKinney's house. It was not seen in place as the quarry was filled with water at the time of visit (April 12, 1920), but its character was determined from the fragments on the dump. These show it to be 2½ to 3 inches thick, to have a bluish-black color, to be composed of compact silica except at the top or the bottom where the flinty part merges into a gray siliceous crinoidal limestone a fraction of an inch thick and to be cut by straight parallel joints, one or more inches apart, which occur in two sets, each being at right angles to the other.

The middle layer was quarried by the roadside on the north side of the creek near Mr. McKinney's house. It is 8 inches thick, bluish black, compact, and dense, and contains many quartz geodes, 3 inches or less in diameter, that are filled with calcite. Much calcite as small grains is disseminated through parts of the chert. Joints are not common so that the shaping of the flint into blocks with rectangular sides is difficult. Three feet of shale that overlies this layer contains considerable chert.

The uppermost layer has been quarried on the north side of the creek and east of the house. It is 7 inches thick and in character resembles very closely the middle layer.

The flint that was quarried by Mr. Lull was hauled in wagons to Iron City where it was shipped and that quarried by Mr. McKinney was hauled in wagons to St. Joseph for shipment.

PHOSPHATE ROCK

Phosphate rock has not been mined in the Waynesboro quadrangle but it is found at several places in the northern part of the quadrangle. All of the rock, so far as observed, is of low grade and contains less than 60 per cent tricalcium phosphate and at few localities does it contain as much as 50 per cent tricalcium phosphate. Practically all of the phosphate rock that is marketed in the United States contains 60 per cent or more tricalcium phosphate and the bulk of it contains 70 per cent or more. Rock with less than 60 per cent can not compete with the higher grade rock, most of which is produced in other parts of Tennessee and in Florida.

There is a great amount of the low-grade phosphate in the quadrangle and new methods of treating phosphate may at some time make these deposits workable. They may, however, not be workable until the

high-grade and cheaply-mined phosphate in other parts of Tennessee and in Florida is nearly exhausted. There is no reason, however, why some of the deposits should not eventually be utilized for local use. The thickness of the deposits and the ease with which they can be mined at some places makes local use possible.

The phosphate is in the Hermitage and Fernvale formations, the Hardin sandstone member of the Chattanooga shale, and the Maury glaunconitic member of the Ridgetop shale. The phosphate in the Hermitage and Fernvale formations occurs in clay and it and the clay are a residue from the weathering of the limestone beds in these formations. That in the Hardin sandstone is disseminated through the sandstone, so that the deposits of it are bedded and consist of hard rock. The phosphate in the Maury is disseminated through a glauconitic sandstone and through a green platy shale and it also occurs as dark nodules in both kinds of rock. The deposits in the Maury are therefore bedded like those in Hardin sandstone.

The most promising occurrences of phosphate, as well as some that will never be of value, are described below. Some of these occurrences have been described by C. W. Hayes.[1]

Along Chief Creek about 1 mile above its confluence with Little Buffalo River, the phosphatic nodule layer of the Maury glauconitic member is 1 foot thick at some places. This, the shale above it, and the Hardin sandstone below it are all phosphatic and all of them taken together make a thickness of about 3 feet of phosphatic beds. The Hardin sandstone at this locality is 15 inches thick and is coarse textured, and its weathered surfaces are brown. Analyses (Nos. 1 and 2 in the accompanying table) of two specimens of the sandstone are given in the accompanying table. The Maury glauconitic member is 4 feet thick and consists of calcareous sandy greenish phosphatic shale that contains phosphate nodules at the base. Analyses (Nos. 3 and 4) of two samples of the shale are given in the accompanying table.

The accompanying section of the Hardin sandstone or Maury glauconitic bed is exposed on Buffalo River half a mile northeast of Voorhies; analyses, as is indicated in the section, have been made of samples from the different beds.

Section on Buffalo River half a mile northeast of Voorhies

		Inches
1.	Very nodular sandstone; analysis No. 5	12–18
2.	Shaly sandstone; analysis No. 6	8
3.	Nodular sandstone; analysis No. 7	12
4.	Shale; analysis No. 8	6

In the vicinity of Riverside and Allens Creek the Hardin sandstone is bluish black and ranges in thickness from a feather edge to 2 feet and

[1]Hayes, C. W., The Tennessee phosphates: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, pp. 7-24, 1896.

an overlying greenish black shale (Maury) in which there are phosphate nodules is generally about 18 inches thick. These beds however probably do not contain as much tricalcium phosphate as they do at the above-described localities on Chief Creek and Buffalo River.

On Trace Creek the Maury glauconitic bed in which there are phosphate nodules is 15 to 18 inches thick and the Hardin sandstone is 12 inches thick.

From near the mouth of Furnace Branch down the valley of Forty-eight Creek for a distance of about 3 miles the Hardin sandstone and Maury glauconitic bed gave good qualitative tests for phosphate in the field but analyses of them from the localities mentioned below show that they have at present no value as a source of phosphate. The Hardin sandstone is usually 6 to 10 feet thick and the Maury glauconitic bed is as much as 3⅓ feet thick. Specimens for an analysis (No. 9) were collected from an exposure of the Hardin sandstone near the junction of Blowing Spring Branch and Little Fortyeight Creek where the sandstone is 10 feet thick. Samples for analyses (Nos. 10 and 11) were obtained from the Hardin sandstone and Maury glauconitic bed on the east side of Fortyeight Creek half a mile south of the mouth of Little Fortyeight Creek. There the Hardin is 10 feet thick and the Maury is 3 feet 4 inches thick. An analysis (No. 12) is given of a sample that was obtained from an exposure of the Maury galuconitic bed on Fortyeight Creek near the mouth of Bowstring Branch, where the Maury is 2½ feet thick. An analysis (No. 13) is also given of a sample that was obtained from the Maury glauconitic bed at a locality on Fortyeight Creek 2 miles south of Fortyeight postoffice where the bed is 2 feet thick.

In the vicinity of Waynesboro the Hardin sandstone is 9 feet thick and is overlain directly by the bluish-black shale of the Ridgetop shale. The Maury glauconitic bed with its phosphate nodules is absent.

The following section was measured by C. W. Hayes[1] at the mouth of Buck Branch 8 miles north of Waynesboro:

(Ridgetop shale)	Feet	Inches
Calcareous black shale		
(Maury glauconitic member):		
Greensand with phosphate nodules	1	0
(Hardin sandstone member of Chattanooga shale):		
Sandy bedded phosphate		5
Shaly bedded phosphate	1	0
Gray sandstone	5	6

The following section was measured by the present writer on Green River, 1 mile south of the mouth of Buck Branch:

[1]Hayes, C. W., Op. cit., section 52 on Plate 52.

	Inches
Ridgetop shale:	
Thinly fissile black clay shale	
Maury glauconitic member:	
Green glauconitic bed	12 to 17
Sandy layer with phosphate nodules as much as several inches in diameter	5 to 10
Chattanooga shale:	
Black thinly fissile clay shale	10
Black phosphatic sandstone	6
Black thinly fissile clay shale	8
Dark-colored phosphatic platy shale	8
Hardin sandstone member:	
Platy phosphatic sandstone	24
Massive gray sandstone	..

Near the mouth of Choat Branch the Hardin sandstone includes at its top 12 inches of shaly phosphate and above this 4 inches of sandy phosphate.[1] This 4-inch layer is in turn overlain by the bluish-black (Ridgetop) shale. The Maury glauconitic bed is not present. Much the same section occurs near the mouth of Bromlet Branch where the Hardin sandstone includes at its top 10 inches of shaly phosphate and above this 17 to 18 inches of sandy phosphate.

The Hardin sandstone on Canoe Branch which enters Buffalo River 2 miles southwest of Flatwoods includes at its top 26 inches of black platy phosphatic sandstone and this is overlain by the Maury glauconitic bed which is here 2 feet thick and consists of green sandy shale and of nodules of grayish-blue phosphate. An analysis (No. 14) is given of the upper 26 inches of the Hardin sandstone and one (No. 15) is also given of the green shale which incloses the phosphate nodules.

The Chattanooga shale is exposed, or has a light covering over an area of 50 yards or more, in the valley of Buffalo River about 1 mile northwest of Flatwoods. In this area it has been much weathered and has settled below its original position due to the removal of the underlying limestones by solution. An analysis (No. 16) of a sample that was obtained from thin phosphatic sandy beds in the shale is given in the accompanying table.

The following section was measured by C. W. Hayes[2] on Short Creek 1 mile east of Lego:

(Ridgetop shale, Maury glauconitic member:)	Feet	Inches
Green sand with phosphate nodules		10
Chattanooga shale:		
Carbonaceous black shale	2	8
(Hardin sandstone member):		
Sandy phosphate		6
Shaly phosphate	1	4
Sandstone and phosphate	2	0

[1]Hayes, C. W., Op. cit., section 51 on Plate 52.
[2]Hayes, C. W., Op. cit., section 49, Plate 52.

A section very similar to the last one was also measured by Hayes[1] 2½ miles east-southeast of Peters Landing.

The accompanying table contains an analysis (No. 17) of a sample from an exposure of the Hardin sandstone on Holly Creek 2½ miles north of Iron City where the sandstone is 2 feet thick and also contains an analysis (No. 18) of a sample of the Maury glauconitic bed 28 inches thick from the same locality.

Limestone in the Fernvale formation at and near the old cement mill in the west part of Clifton has completely disintegrated, leaving its insoluble constituents which are mainly clay and phosphate. The residual clay as it is exposed in gullies is as much as 12 feet thick and the lower 6 feet of it contains gray and brown grains of phosphate. Analyses (Nos. 19 and 20) of two samples of this phosphate-bearing clay which are given in the accompanying table show that they contained 32.21 and 50.05 per cent of tricalcium phosphate. Separation of the phosphate from the clay might yield concentrates with 70 per cent or more of tricalcium phosphate, and if so the phosphate would be salable. The extent of the phosphate-bearing clay however is not known, but the facts that the clay lies in a horizontal or nearly horizontal position and that the exposures are on the edge of a gently rolling area would seem to indicate that it underlies at least a few acres.

The Fernvale formation is exposed along both sides of Beech Creek from Mooney southeastward for a distance of about 2 miles. The exposures form several gently rolling benches each of which comprises an area of 100 acres or less; and on the benches the limestone in the formation has disintegrated, leaving a phosphate-bearing clay. This clay produces a very rich soil as is attested by the good crops which it produces. This clay is as much as 10 feet thick and an analysis (No. 21 in table) shows that it contains 3.46 per cent of phosphorus pentoxide (P_2O_5) which is equivalent to 7.56 per cent of tricalcium phosphate. It is possible that parts of the clay may contain enough phosphate to justify the recovery of the phosphate for commercial purposes.

The Hermitage formation is exposed on the north side of Eagle Creek, 3 miles south-southeast of Clifton, and its top has disintegrated into a phosphate-bearing clay which is probably several feet thick over an area of 50 acres or more. This clay gave good qualitative tests for phosphate at several places in the field and a sample was collected for analysis. The analysis (No. 22 in table) shows that it contains 6.31 per cent of phosphorus pentoxide (P_2O_5) which is equivalent to 13.78 per cent of tricalcium phosphate.

The Hermitage and Fernvale formations are the surface rocks over an area of about three-fourths of a mile square just south of Glenkirk and they have disintegrated to a great extent, producing clay which is

[1]Hayes, C. W., Op. cit., section 50, Plate 52.

at least several feet thick. This clay forms a very fertile soil as is attested by the good crops it produces. Its fertility is due in large part to small grains of phosphate disseminated through it. Prospecting in this area might reveal places where the phosphate is in sufficient quantity to be mined, treated, and marketed.

Analyses of phosphate rock from the Waynesboro quadrangle.
(Paul C. Bowers, analyst.)

	Bed	Thickness in ft.	Locality	Phosphorus pentoxide (P_2O_5)	Tricalcium phosphate $Ca_3(PO_4)_2$	Alumina (Al_2O_3)	Ferro-oxide (Fe_2O_3)
1	Hardin sandstone.....	1¼	Chief Creek.....	22.27	48.64	1.15	3.69
2	Hardin sandstone.....	1¼	Chief Creek.....	23.86	52.11	1.19	3.26
3	Shale in Maury glauconitic member.....	4	Chief Creek.....	2.8	6.12	.....	.....
4	Shale in Maury glauconitic member.....	4	Chief Creek.....	5.7	12.45	.....	.....
5	Nodular sandstone in Maury glauconitic member or Hardin sandstone.....	1½	Buffalo River near Voorhies.....	23.26	50.8	.86	1.22
6	Shaly sandstone in Maury glauconitic member or Hardin sandstone.....	⅔	Buffalo River near Voorhies.....	6.38	13.93	.....	.....
7	Nodular sandstone in Maury glauconitic member or Hardin sandstone.....	1	Buffalo River near Voorhies.....	6.14	13.41	.....	.....
8	Shale in Maury glauconitic member or Hardin sandstone....	1½	Buffalo River near Voorhies.....	.38	.83	.....	.....
9	Hardin sandstone....	10	Near junction of Blowing Spring Branch with Little Forty-eight Cr.....	3.00	6.55	.....	.....
10	Maury glauconitic member.....	3⅓	East side of Forty-eight Cr. ½ mi. south of mouth of Little Forty-eight Cr.....	12.9	28.17	.....	.....

11	Hardin sandstone.....	10	East side of Forty-eight Cr. ½ mi. south of mouth of Little Forty-eight Cr.....	.54	1.18	.....	.....
12	Maury glauconitic member.....	2½	Forty-eight Creek near mouth of Bowstring Br.....	1.02	2.23	.....	.....
13	Maury glauconitic member.....	2	Forty-eight Creek 2 miles south of Forty-eight p. o....	9.4	20.53	.....	.....
14	Hardin sandstone.....	2⅙	Canoe Branch.....	4.44	9.70	.....	.....
15	Maury glauconitic member.....	2	Canoe Branch.....	11.3	24.68	.....	.....
16	Phosphatic layers in Chattanooga shale....	2+	1 mi. northwest of Flatwoods.....	10.3	22.5	.....	.....
17	Hardin sandstone.....	2	Holly Creek 2½ mi. north of Iron City.	1.08	2.36	.....	.....
18	Maury glauconitic member.....	2⅓	Holly Creek, 2½ mi. north of Iron City .	14.55	31.78	.....	.....
19	Phosphate-bearing residual clay from limestone in the Fernvale formation.....	6	Cement mill at Clifton.....	14.75	32.21	.....	.....
20	Phosphate-bearing residual clay from limestone in the Fernvale formation.....	3	Cement mill at Clifton.....	23.45	50.05	7.66	6.68
21	Phosphate-bearing residual clay from limestone in the Fernvale formation.....	10	Mooney.....	3.46	7.56	.....	.....
22	Phosphate-bearing residual clay from Hermitage formation..	6+	Eagle Creek, 3 mi. southeast of Clifton.....	6.31	13.78	.....	.....

BUILDING SAND

Building sand used in the quadrangle is shipped into the area or is obtained from the comparatively small number of sand bars along the streams. Some of the pockets of yellow to red sand that are encountered in the iron mines would furnish a considerable amount of sand, and the Eutaw sand which caps the ridges in the southwest corner of the quadrangle is suitable for building.

CLAYS

Surficial clays suitable for making common building bricks are present at many places in the quadrangle. Such bricks have been made from surficial loams at Collinwood and Waynesboro; they were made several years ago from an alluvial clay in a stream flat near the railroad station at Iron City; they have been made from similar clays on Little Buffalo River at Strathmore, and also along Furnace Branch. The bricks that were made at the last-named place were used in building the stack of Wayne furnace which was operated many years ago.

An exposure of white clay occurs on the west slope and near the crest of a hill 1 mile south of Clifton. The clay occurs as a horizontal bed apparently 25 to 30 feet thick; it has been derived from the weathering of the Ridgetop shale and is overlain on the crest of the hill by 25 feet of the Fort Payne chert. It is highly plastic; it contains very little sand; and in it there is still preserved the lamination and fossil casts of the original shale. It is stained by iron oxide along some of the joints and sufficient iron oxide has penetrated the clay along two vertical joints to harden it several inches away from the joints. This clay has been used locally as a fire clay in putting up boilers for sawmills and other purposes. It has also been used to some extent in making fire bricks which are said to have had a cream color.

GRAVEL FOR CONCRETE

Gravel has been used in making concrete at Collinwood and Waynesboro. The gravel at Collinwood was obtained from a pit in the Tuscaloosa gravel half a mile northwest of the town. A description of it and the results of physical tests of a sample from this locality are given on pages 25 and 144.

The gravel at Waynesboro is obtained from gravel bars along Green River at that place. These bars here as well as those along practically all other streams are very numerous and large and afford clean gravel. The pebbles in them consist entirely of chert and they vary in size from a small fraction of an inch to several inches in diameter. Many of them are well-rounded; but some are angular. The stream gravels contain a larger proportion of angular pebbles than the Tuscaloosa gravel does.

RAILROAD BALLAST

The chert pebbles and fragments which are separated from the iron

ore in the iron-ore washing plants at Allens Creek, Pinkney, Corning, Hardwick, and Iron City are well adapted for railroad ballast and are extensively used for this purpose. This material has the advantage of being free from clay, and its size is more or less uniform, being one inch or less in diameter. It is simply a by-product from the washing plants. the chert pebbles and fragments are fairly soft, and they would thus not be suitable for making macadamized roads with firm durable surfaces.

Slag from iron furnaces at Florence and Sheffield, Alabama, has been used for ballast to a great extent along the Louisville & Nashville and Tennessee Western railroads. Slag from Anna Furnace at Collinwood has also been used for ballast.

ROAD MATERIAL

All parts of the quadrangle are reached by public roads, most of them in poor condition. Many of the roads pass through areas where gravel and chert are the surface rocks and in such areas parts of them have good natural surfaces. The Clifton-Waynesboro pike running from Clifton to Waynesboro has a macadamized surface, and the Jackson Military Highway running northeastward through St. Joseph also has a macadamized surface. In April, 1920, plans were being made to macadamize the Waynesboro-Lawrenceburg Road.

An abundance of good road material occurs in all parts of the quadrangle. Such available material includes (1) the residual cherts of the Fort Payne chert and St. Louis limestone, (2) the Tuscaloosa gravel, (3) gravels in the terrace and alluvial deposits, and (4) the limestones. The abundance of chert and gravel and the low cost at which they can be mined and prepared for road building, in comparison with the high cost of quarrying and crushing the limestone, probably mean that the limestones will be used very little or none in building roads in the quadrangle.

The residual cherts from the Fort Payne chert and St. Louis limestone occur over large areas in all parts of the quadrangle but the most suitable bed of chert in them occurs in the southeast part of the quadrangle. This bed is as much as 50 feet or more thick and comprises the upper part of the Fort Payne chert and the lower part of the residual chert of the St. Louis limestone. The chert in the bed is generally fairly hard, so that it would be durable; it is much fractured so that it can be quarried easily; and it has sharp edges which will tend to make it bind. Furthermore it contains some clay which would facilitate the binding of the chert and thus make a firm smooth road. This chert could be used simply as it comes from the pits but the sizing of it would make a smoother and better compacted road. A record of a test on chert from this bed is given in the accompanying table.

A road material pit that is probably in residual chert of the lower part of the St. Louis limestone has been opened and worked in recent years on a gentle west hillslope one-fourth mile west of St. Joseph.

(See Plate XIII, A). The pit when visited in April, 1920, had an area of between 1¼ and 1½ acres and had a face of 15 feet on the east side. It had been worked by means of a steam shovel and about 10,000 cubic yards of material had apparently been removed from it. The chert in which the pit was made is fairly hard and somewhat porous, is cut by numerous fractures and is gray though the small amount of red clay intimately mixed with it gives the surfaces of the pieces a red color. The quantity of available chert at this and nearby localities is very great and will be sufficient to build roads in this vicinity for many centuries. The quantity of such chert at this locality is, however, no greater than it is at numerous other localities in the southeast part of the Waynesboro quadrangle.

The chert from the pit near St. Joseph was used on the Jackson Military Highway which runs northeastward through St. Joseph and was so used without being sized or crushed. The chert thus used on this highway binds well and makes a smooth gray surface. The accompanying tests of a sample of chert collected by the writer from the east face of the pit were made by the Bureau of Public Roads, U. S. Department of Agriculture.

Tests of road material from the Waynesboro quadrangle

GRAVEL

(Mechanical analysis)	1 Per cent		2 Per cent	
Retained on 3 inch screen				
Passing 3 inch retained on 2½ inch screen			12.1	
Passing 2½ inch retained on 2 inch screen	12.6		0.0	
Passing 2 inch retained on 1½ inch screen	6.9		8.2	
Passing 1½ inch retained on 1 inch screen	25.3	100.	16.1	100.
Passing 1 inch retained on ¾ inch screen	23.4		14.2	
Passing ¾ inch retained on ½ inch screen	16.6		21.4	
Passing ½ inch retained on ¼ inch screen	15.2		28.0	
Passing ¼ inch screen	33.3		22.1	

SAND

(Mechanical analysis)				
Retained on ¼ inch screen	66.7		77.9	
Passing ¼ inch, retained on 10 mesh	18.6		38.8	
Passing 10 mesh, retained on 20 mesh	7.7		12.3	
Passing 20 mesh, retained on 30 mesh	1.9		6.0	
Passing 30 mesh, retained on 40 mesh	1.0		5.6	
Passing 40 mesh, retained on 50 mesh	0.5	100.	5.2	100
Passing 50 mesh, retained on 80 mesh	0.8		8.6	
Passing 80 mesh, retained on 100 mesh	0.3		1.9	
Passing 100 mesh, retained on 200 mesh	0.5		1.5	
Passing 200 mesh	68.7		20.1	
	Cementing value		Cementing value	
	115.		27.	

1. Residual chert from the St. Louis limestone, from pit one-fourth mile west of St. Joseph.

2. Tuscaloosa gravel from pit half a mile northwest of Collinwood.

The Tuscaloosa gravel is widely distributed on the hills and ridges in the quadrangle and is as much as 150 feet thick. It is an excellent and accessible road material and the quantity is so great as to be practically inexhaustible. Its character, thickness, and distribution are more fully discussed on page 25.

A pit which is in the Tuscaloosa gravel half a mile northwest of Collinwood has furnished gravel for concrete, railroad ballast, and road building at that place. The gravel consists of hard gray chert pebbles which are fairly to well-rounded and are 4 inches or less in their longest dimension. There is comparatively little clay and sand mixed with it. The accompanying tests of a sample collected by the writer from a car of the gravel at Collinwood were made by the Bureau of Public Roads, U. S. Department of Agriculture.

Some of the streets in Collinwood have been paved with gravel from the above-mentioned pit. Of these, Broadway, the main thoroughfare, was the first to be paved, the work having been done 5 years before the writer's last visit (April, 1920). At that time the surface was still firm and smooth except for the very few cobbles which protruded slightly above the general surface. Repairs had been made at only one place within the 5 years.

The gravel at the above-described pit is probably 40 to 50 feet thick and underlies many square miles at and near Collinwood. On the crest of the broad ridge on which this town is situated the gravel is overlain by a few feet of red clay and surficial loam, but on the slopes of the ridge, as at the pit, it reaches the surface.

A pit in the Tuscaloosa gravel from which gravel was obtained for use on the Waynesboro-Clifton pike is located on the crest of a ridge and at the edge of the pike 2 miles northwest of Waynesboro. It was sunk to a depth of 10 feet without reaching the base of the gravel. The pebbles consist entirely of hard gray chert; they are well-rounded; they range in size from that of a pea to 4 inches in diameter, and they show little or no assortment according to size. A few thin veins of iron oxide lie in a horizontal or nearly horizontal position, but they are not so numerous or so thick that they make mining difficult or injure the use of the gravel for road material. The Tuscaloosa gravel occurs along this pike for a distance of about 3 miles so that the locality at which the above-described pit has been made is only one of the numerous places where such pits could be made.

Gravel of the same character as that at the above-described pits could be mined at hundreds of other places in the quadrangle and the cost of mining would be no greater at such places than at these two pits.

Gravels comprise a very large part, perhaps half or more, of the terrace and alluvial deposits. The terrace deposits are most numerous

along Buffalo and Tennessee rivers, but the alluvial deposits occur along all of the larger and most of the smaller streams where gravel bars are very numerous and large. Many single bars cover an area of several acres. The quantity of such gravel is therefore very great and the deposits are easily accessible. Gravel from the bars along Eagle Creek has been used extensively and successfully along the Clifton-Waynesboro pike.

The gravel in the terrace and alluvial deposits consists almost entirely of chert pebbles which are subangular to well-rounded in shape, and which range in size from a fraction of an inch to several inches in diameter. They in fact resemble very closely in character the Tuscaloosa gravel that is on most of the hills and ridges in the quadrangle, though they are somewhat more angular than the gravel on the hills and ridges.

The different limestones in the quadrangle, especially the Decatur, Bob, Lego, Laurel, Osgood, and Brassfield limestones, would make good road material. The Lego, Laurel, and Osgood limestones have been quarried extensively at Newsom, Tenn., for road building. Thus far none of these limestones have been used for this purpose in the Waynesboro quadrangle and it is not likely that they will be extensively used on account of the abundance and accessibility of the gravel and chert in all parts of the quadrangle. The accompanying tests on a sample of the Laurel limestone collected by the writer from the quarry at the station at Iron City were made by the Bureau of Public Roads, U. S. Department of Agriculture. They indicate that this limestone is suitable for building roads for light traffic only.

Test results of Laurel limestone at Iron City

Specific gravity	2.69	
Weight per cubic foot, in pounds	168.	
Water absorbed per cubic foot (0.47 pounds)	0.28	per cent
Per cent of wear	5.0	
French coefficient of wear	8.0	
Hardness	15.0	
Toughness	8.0	

Slag from Anna Furnace, a blast furnace, at Collinwood has been used in paving roads and streets at Collinwood.

COAL

Lenses of coal, a fraction of an inch thick, occur in the Chattanooga shale at some places. They were observed on Pinhook Branch near Iron City and on Bundrant Branch, a tributary of Indian Creek and a lens was found in a dug well 12 feet deep on the John Burns place on Beckman Branch 3½ miles north-northeast of Martins Mills. The lens

on Pinhook Branch is one-sixteenth of an inch thick and that on Bundrant Branch is one-eight of an inch thick. It is said that enough of the mineral was obtained from the well on the Burns place to fill a cigar box. Mr. Burns gave the writer a sample of the coal from his well and it was submitted to E. Theo Erickson, of the U. S. Geologieal Survey, to determine whether it was coal or a natural hydrocarbon. Mr. Erickson's report follows.

"The sample heated in a tube gave evidence of intumescence (partial melting), followed by the production of considerable distillate. The odors were coal-like. Considerable ash was also obtained. The sample is slightly soluble in chloroform and benzene at ordinary temperatures. The solubility in carbon disulphide is not much more than that in the above named solvent. The physical properties (definite planes of fracture) of the sample resemble those of coal rather than those of the natural hydrocarbons in which it is more or less conchoidal. The above tests indicate the sample to be a variety of soft coal."

The Chattanooga shale is widely exposed in the Waynesboro quadrangle and in other parts of the United States and at no place does it contain workable coal beds.

OIL AND GAS

OCCURRENCE IN THE WAYNESBORO QUADRANGLE

The Chattanooga and Ridgetop shales contain a small quantity of oil which may be detected by the odor of fresh pieces of the shale but they probably do not contain over a few gallons to the ton. The oil could be recovered only by mining the shale and distilling the oil from it, but its recovery would probably not be economical under present conditions unless the yield were well over 20 gals. to the ton of shale. Samples of the Chattanooga shale obtained by Dr. Geo. H. Ashley at Bakers and Newsom, Tenn., near Nashville, contained from none to 9.1 gallons of oil and from 835 to 1,916 cubic feet of gas per short ton.[1] This shale near Hamburg, Tenn., about 15 miles west of the Waynesboro quadrangle, contains so much bituminous matter, including oil, that a large pile of the fresh shale dumped at the edge of Tennessee River near that place caught on fire from spontaneous combustion and burned for about two months.[2]

Showings of oil and gas on the surface and in shallow wells are reported at a number of places in the northwest part of the quadrangle but the most noteworthy occurrences thus far discovered are in 4 wells at Iron City.

In 1892 or 1893 a well (No. 1) was drilled at that place to a depth of 315 feet where gas was struck. The flow of gas was so strong that it blew the drill out of the well, but it decreased enough in 2 or 3 days for the well to be capped without difficulty. The gas was burned at

[1]Ashley, G H., Oil resources of black shales of the eastern United States: U. S. Geo. Survey Bull. 641, pp. 316-319, 1917.

[2]Bowers, Paul C., An interesting case of spontaneous combustion: The Resources of Tennessee, vol. 6, pp. 37-40, 1916.

times for 2 or 3 months; but, as its utilization was not undertaken on account of the fiancial panic at the time, a poplar plug was driven deep into the well to prevent the escape of gas.[1] At the time of the writer's visit in 1914 the strong sulphur water that was encountered at a depth of 200 feet was being used for drinking. The sulphur water probably comes from near the base of the Bigby limestone and the gas probably came from the Hermitage formation.

A second well (No. 2), known as the Seavy-Lull well, was begun in December, 1914, 300 feet west of the above-described well, but owing to a crooked hole it was abandoned March 1, 1915, after it had been drilled to a depth of 261 feet. Mr. E. L. Lull, a mining engineer, who had charge of the drilling, reports that an estimated flow of 5,000 cubic feet of gas per 24 hours with a rock pressure of about 20 pounds per square inch was obtained from the Bigby limestone at a depth of 182 to 205 feet. He also reports a trace of gas and oil from the Hermitage formation at and near the bottom of the well.

A third well (No. 3) at Iron City was begun by the Florence-Sheffield Oil and Gas Co. in the summer of 1919, 100 feet east of well No. 1 and was drilled to a depth of 341 feet. Mr. E. L. Lull who was connected with the above-named company makes the following statement concerning the well.[2]

"Gas was found at 299 feet to 311 feet, there being a fairly well developed sand. This checks the report on the old well (No. 1) at Iron City, the present well being drilled about 100 feet east of the old well and about 500 feet east of the one (No. 2) drilled in 1914-15. * * *

"Unfortunately, however, the old well (No. 1) was not plugged in first class shape and there is a leak of sulphur water in same through the plug below the 200-foot level and from this source out into the gas horizon at about 300 feet.

"This flow of water has apparently shut off the gas as we are obtaining about 50 gallons per 24 hours of this sulphur water (characteristic at 200 feet in old well) at the gas horizon in the present well."

A fourth well (No. 4) at Iron City was begun by the Florence-Sheffield Oil & Gas Co. in the fall of 1919 near the Iron City Spring at the west edge of the town. It was drilled to a depth of 880 feet. A small flow of gas is reported from the Carters limestone at the depths, 420 to 424 feet and 500 to 505 feet; a show of oil is reported to have been found in this limestone at a depth of 440 to 444 feet; and a trace of both oil and gas is reported to have been found in the beds of limestone that are older than the Carters.

Practically complete sets of cuttings from the last three wells (Nos. 2, 3, and 4) were carefully saved by Mr. Lull and were sent to the writer for examination. A few fragmentary fossils found in the cuttings

[1]This information was furnished the writer by the late Captain H. P. Seavy who was a prominent citizen of Iron City.

[2]Letter of Oct. 1, 1919, addressed to H. D. Miser.

were examined and reported upon by Mr. E. O. Ulrich. Records of these wells are given on pages 27 to 35.

In April, 1920, the Florence-Sheffield Oil & Gas Co. began a well on Brewer Branch just south of the depot at Wayland Springs, but drilling was soon discontinued. Cuttings from this well were not examined by the writer. The first hard rock encountered after passing through the gravelly stream wash was probably limestone in the Wayne formation. This well is on the southwest flank of the Wayland Springs anticline, the crest being from 1 to 3 miles farther northeast.

A well, 1,512 feet deep, was drilled at Collinwood in 1919 with the hope of obtaining either oil or a large supply of water. Neither oil nor gas was found in this well, but at 1,512 feet sulphur was encountered. A partial log of the well is given on page 36.

A well in search of oil is now (April, 1920) being drilled near Riverside.

ACCUMULATION IN THE WAYNESBORO QUADRANGLE

As stated above the rocks of the Waynesboro quadrangle consist predominantly of limestone. Not only the limestone but some of the shale and chert are made up in large part of fossils. These fossils are the remains of animals that were buried in the sea while the sediments that later hardened into the rocks of this area were being laid down, and they may have been the source of much oil and gas. In addition the Chattanooga and Ridgetop shales contain carbonaceous matter that may have been a source of these substances. Although these sources may have furnished much oil and gas and although the domes and anticlines that are described above are a favorable type of structure for the accumulation of oil and gas, there appear to be, if we may judge from our present knowledge of the region, no porous reservoirs that could contain large quantities of these substances. There, however, is a possibility that oil and gas may be found in commercial but not relatively large quantities in cracks and crevices.

The rocks of Carboniferous and Upper Cretaceous age are the surface rocks over most of the quadrangle, and while those of Silurian and Devonian age are exposed in comparatively small areas, such areas occur in most parts of the quadrangle. Much if not most of the oil and gas that the rocks of Silurian, Devonian, Carboniferous and Upper Cretaceous age may have once contained have therefore reached the surface and there escaped.

In Allen County, Kentucky, adjoining Tennessee, oil is found in porous sandy and dolomitic limestones of Silurian and Devonian age, which underlie the Chattanooga shale, the probable source of the oil.[1] In the Waynesboro quadrangle the Chattanooga shale is usually so thin that it probably could not have been the source of very much oil.

[1] Shaw, E. W., and Mather, K. F., The oil fields of Allen County, Kentucky: U. S. Geol. Survey Bull. 688, pp. 40-48, 85, 1919.

On the other hand, the rocks overlying and immediately underlying the Chattanooga are, as stated above, so widely exposed in the northwest half and southeast part of the quadrangle that if they were porous enough to retain oil they would not retain it in these parts of the quadrangle. The only bed that appears to be sufficiently porous is the Hardin sandstone member at the base of the Chattanooga shale.

Oil and gas if present in large quantities are more likely to have been retained in the Ordovician than in the younger rocks. The exposed rocks of this age are the Fernvale, Arnheim, Leipers, and Hermitage formation, named in order of their age with the youngest first.

The Fernvale formation is composed of shale in its upper part and of hard dense limestone in its lower part, and is exposed in the northwest, northeast, and southeast parts of the quadrangle. Owing to the density of the limestone it is not likely to contain much oil and gas in the central, west-central, and southwest parts of the quadrangle where it is concealed. In some parts of the area it might be a seal to keep them from escaping upward from formations beneath. The shale in its upper part is thin and probably at no place exceeds 20 feet in thickness. The only known occurrence of the Arnheim limestone in the quadrangle is at an exposure on the right bank of Tennessee River at Clifton. The Leipers limestone contains some shale that might act as a seal for oil and gas but the interbedded limestone layers are not porous and hence could not hold much oil and gas even where the limestone is favorably situated for their accumulation and retention. The limestone is exposed in the southeast part of the quadrangle and would not now yield any oil and gas there if it ever contained them, It may underlie the northeast, central, and southwest parts of the quadrangle but it is absent in the northwest part. The Bigby limestone has been penetrated in the 4 wells at Iron City as above stated. A flow of gas estimated at 5,000 cubic feet per 24 hours with a rock pressure of 20 pounds per square inch is reported to have been obtained from the base of the Bigby in the second well (No. 2) drilled at that place. The gas may occupy fissures in the limestone but further drilling in the region seems necessary to prove this.

The Hermitage formation being composed of interbedded shale and limestone in about equal proportions, is probably the most impervious cap for oil and gas in the rocks of Ordovician age. If it should at any place be porous enough, it might yield paying quantities of oil and gas in the east half and southwest quarter of the quadrangle; but it could not be expected to yield these substances in those domes in the northwest part of the quadrangle where the streams have cut their valleys in the Hermitage to a depth of as much as 80 feet. The exposed limestone layers in this formation are fine grained and are not porous. They thus could not be the reservoir for any considerable quantity of oil and gas. Relatively small quantities of them may however be found

in fissures. The flow of gas from the earlier-drilled well (No. 1) at Iron City and traces of gas and oil from later wells (Nos. 2 and 3) at that place are from the Hermitage formation.

The Hermitage formation and Bigby limestone of the Waynesboro quadrangle are of Trenton age. Rocks of this age are still looked upon with favor by many drillers because the rocks that supply the northeastern Indiana and northwestern Ohio (Lima-Indiana) field are generally regarded as of Trenton age. Such a view regarding the rocks of Trenton age in the Waynesboro quadrangle is a mistake because they differ from those in the above-named oil-producing parts of Indiana and Ohio. There the oil-producing limestones have been made porous by the process of the changing of the limestone to dolomite[1] whereas the limestones of Trenton age in the Waynesboro quadrangle have undergone no such change.

Rocks of Ordovician age older than the Hermitage are not exposed in the Waynesboro quadrangle. One well (No. 3) at Iron City has however penetrated the underlying Carters limestone to a depth of 15 feet and another well (No. 4) at that place has penetrated the Carters and still older limestones to a depth of 509 feet. Also a well at Collinwood, which is 1,512 feet deep, penetrated the Carters and older limestones to a depth of about 806 feet. The available cuttings of these limestones from these wells, of which records are given on pages 31 to 37, consist almost entirely of compact very fine-grained light-colored limestone which breaks with a conchoidal fracture. Traces of gas were found in three beds of these limestones at Iron City and traces of oil were also found in two beds of them at that place. If traces of either oil or gas were found in the 1,512-foot Collinwood well their discovery has not been reported to the writer. The discovery in that well of a strong flow of sulphur water which is said to have risen 1,000 feet within 15 minutes after the water-bearing rocks were penetrated, suggests that the water came from a highly porous bed. If the sulphur-water-bearing rocks thus occur in a bed, this bed would probably be porous enough to hold commercial quantities of oil or gas. But the fact that this well was drilled on the crest of the principal anticline in the Waynesboro quadrangle without finding oil or gas, means there is no great hope of discovering oil unless future wells are drilled deeper into the Ordovician rocks than the 1512-foot Collinwood well. It, as previously stated, penetrated the Carters and older limestones to a depth of about 806 feet, and may have passed into the Knox dolomite of Lower Ordovician and Upper Cambrian age. The Knox is exposed in the Wells Creek Basin in the southwestern part of Stewart County and in a large part of the Valley of East Tennessee. It is a massive, dense dolomite and is probably at least several hundred feet thick in the Waynesboro quadrangle and

[1]Orton, Edward, The Trenton limestone as a source of petroleum and natural gas in Ohio and Indiana: U. S. Geol. Survey, Eighth Ann. Rept., pt. 2, pp. 582-587, 1889.

other parts of Central Tennessee. The Ordovician rocks above the Knox crop out in the Central and Wells Creek basins and aggregate a thickness of about 800 feet. The exposures of the rocks between the Knox and the Hermitage show that they are close textured and contain no pores large enough for the collection of commercial quantities of oil and gas.

The Ordovician rocks in the Central Basin have been penetrated in both deep and shallow wells at a number of places. Concerning the presence of oil and gas in them there Dr. A. H. Purdue made the following statement.[1] "There are numerous localities over the Central Basin where a small amount of gas and some oil have been sealed in, and these are not infrequently struck in drilling for water. But the oil is insignificant in amount where it occurs at all, and the gas usually exhausts after a few days' flow. The greatest supply of gas they could be expected to furnish would be for private use, such as heating a residence, or a kitchen range. In most cases, the supply would be too small to justify piping even for one of these purposes."

CONCLUSION

Oil and gas have not been found in paying quantities in the quadrangle. The possibility of finding them in the rocks above the Knox dolomite is probably greater than in the Knox. The well that is 1,512 feet deep at Collinwood may, as previously stated, have passed into the Knox dolomite. If so this and the wells at Iron City have perhaps penetrated all of the possible oil and gas-bearing beds that occur above the Knox. The failure of the deep well at Collinwood, which was drilled on the crest of the largest anticline in the area, and the poor showings of the wells at Iron City, which were also located on an anticline, discourage the idea that oil and gas in commercial accumulations exist in the Waynesboro quadrangle. However the histories of other districts where oil and gas in payable quantity has been found near barren wells are evidence that until more extensive prospecting has been done the condemnation of the entire quadrangle is not justified, and that the possibility of the discovery of commercially valuable bodies of oil and gas remains. The unfavorable results thus far obtained should be borne in mind by any one who contemplates testing the oil and gas prospects of the region, and further drilling should not be begun without a full realization that the chances for failure are much greater than the chances for success. Any prospecting that is to be carried on should be done on or near the crests of the domes and anticlines.

[1]Purdue, A. H., Oil and gas conditions in the Central Basin of Tennessee: The Resources of Tennessee, vol. 6, p. 12, 1916.

WATER RESOURCES

GENERAL UNDERGROUND WATER CONDITIONS

Conditions are favorable in the Waynesboro quadrangle for an excellent and abundant supply of drinking water and a considerable quantity of water for irrigation and for water power. Few places in any country have so many permanent springs over an equal area as are found here. The quadrangle has an annual precipitation of about 50 inches which is fairly evenly distributed through the different seasons.

The nature and structure of the rock beds are specially favorable for the storing of the rainfall and keeping the water pure. The topmost rock beds, over practically the whole area, are porous cherts, sands and pebble beds, all of which act like a sponge in absorbing and holding the water in a pure state and allowing it to drain out gradually at lower levels. The structure of the rock beds favors a considerable regularity in the distribution of springs and in their flow. The more elevated parts of the central and southwestern portions of the quadrangle are capped by almost horizontal beds of sand, gravel, and conglomerate (Tuscaloosa gravel and Eutaw sand) of Upper Cretaceous age. These beds readily absorb the rainfall and allow it to drain out at its borders on the hill slopes. A good example of the effect of such rock beds occurs on the hills between the headwaters of Weatherford Creek, Second Creek and Cypress Creek. The flow of these streams is kept quite regular during the year, being maintained during very dry seasons by the almost innumerable springs that flow from the borders of these capping beds of rock.

The structural features of the beds of Paleozoic age, as previously explained, are such that usually the rock beds slope gently in the direction that the overlying surface slopes. The rainfall readily sinks into the porous cherts of the St. Louis and Fort Payne formations and then gradually runs down the sloping beds and drains out as springs in the sides of valleys, and along streams where the edges of the chert beds are exposed. There is but little material in these rock beds that will dissolve in the water, as it percolates through them, so the springs issue almost free from salts and afford excellent drinking water.

The limestone formations of Ordovician and Silurian age are also favorable for springs, and many large ones flow from beds in these formations, but the water contains more or less lime in solution and is not so good for household use as the water coming from the higher and more siliceous beds.

The valleys, as is explained above, are well supplied with water from springs; but, where spring water is not available, wells 50 feet or

less in depth generally obtain a sufficient supply for farm use. Water on the upland areas is obtained from wells and cisterns. At and near St. Joseph a sufficient supply of water for stock and household use is obtained from wells that generally range from 30 to 40 feet in depth; but in the other upland areas of the quadrangle the ground-water level is farther below the surface in consequence wells will probably have to be sunk to a depth of 50 feet or more at most places and probably 100 feet or more at numerous places.

Several deep wells, some of which will be more fully described below under the heading "Town Supplies," have been drilled in the quadrangle. They are at Iron City and Collinwood. Some of them were drilled in search of large water supplies and others for petroleum. The wells at Collinwood, located on an upland area, obtained some water at a depth of about 50 feet, a fairly large quantity of it at a depth of 265 to 270 feet, and a strong flow at a depth of 1512 feet. The water down to a depth of 270 feet is pure water suitable for all common uses but that from a depth of 1,512 feet is sulphur water. These facts, together with the probability that ground-water conditions are similar in all of the upland areas strongly suggest that deep drilling in other upland areas will also probably find pure water to extend 250 to 275 feet below the surface and will probably find sulphur water at a greater depth. The other deep wells, of which records are given on pages 27 to 35, were drilled at Iron City. They were drilled in a valley at that place and the fact that only sulphur water was found in them suggests that it is probably useless to drill deep wells in the other valleys of the quadrangle to obtain pure water.

TOWN SUPPLIES

The water supply for Iron City is obtained in large part from the Iron City Spring, which is on the west edge of the village. This spring issues from the base of a lense of limestone in the lower part of the Ridgetop shale and the minimum flow according to E. L. Lull is 9 gallons per minute. The water is pumped into a tank on the top of the hill just north of the spring and from there it is piped to several places in the village. The analysis (No. 1) in the accompanying table shows this to be a water of low mineral content. The chief constituents are calcium and bicarbonate. The hardness is low in comparison with waters used regularly in many places, but is appreciably greater than that of some other waters in the quadrangle. On the basis of the mineral constituents the water would be classed as good for all ordinary domestic and industrial uses. This and other analyses given in the table do not furnish any basis for an opinion as to the sanitary quality of the waters and statements based on these analyses do not take into account possible
ion which might render the waters unsafe for drinking.

A strong sulphur water was found in a well at Iron City at a depth of 200 feet and was found in a second well 100 feet east of the first well at a depth of between 299 and 311 feet. This water is used by a few people for drinking. An analysis of water from the 200-foot well (analysis No. 2) in the accompanying table shows a very high mineral content. Sodium chloride (common salt) makes up over half the dissolved mineral matter. The water is exceedingly hard and contains such excessive quantities of all constituents as to be of little value for most industrial and household uses.

The water supply for the town of Collinwood and the iron furnace and wood products plant has been obtained from cisterns, from Dunn's Spring, and from seven wells at a depth of 265 to 270 feet; but it is inadequate and in the summer of 1920 the decision was made to pipe water a distance of 3 miles from the headwaters of Shanatee Creek, which is east of Collinwood. In 1919 a well was sunk to a depth of 1,512 feet in search of petroleum and a greater water supply. No petroleum was found but in the bottom a strong flow of sulphur water, which rose 1,000 feet in 15 minutes, was found. A partial log of one of the shallow wells and also a partial log of the deep well are given on pages 36 and 37. The water from the seven wells mentioned above is obtained from beds near the middle of the Fort Payne chert and the sulphur water in the deep well came from a bed of Ordovician age which is probably older than the Carters limestone. Analyses of water from Dunn's Spring, from Shanatee Creek and from well No. 8, are given in the accompanying table (Nos. 3, 4, and 5). All are soft waters of low mineral content and on the basis of the mineral constituents should be classed as excellent for all ordinary domestic and industrial uses.

The water supplies for Clifton and West Point are obtained from cisterns and shallow wells, that for Waynesboro is obtained from cisterns, shallow wells, and springs, and that for Wayland Springs is obtained from several springs.

At Allens Creek a spring issues from near the base of the Fort Payne chert about 100 feet northwest of the railroad station and although it has a small flow it furnishes drinking water for many of the inhabitants of the village. An analysis of water from this spring is given in the accompanying table (No. 6). The water is soft and contains only a small quantity of dissolved mineral matter. This analysis indicates that with reference to its mineral constituents the water is excellent for all ordinary domestic and industrial uses.

Mineral analyses of waters from Waynesboro Quadrangle, Tennessee

(Parts per million. Analyzed by Margaret D. Foster, U. S. Geol. Survey.)

	1	2	3	4	5	6
Silica (SiO_2)	9.2	12.	7.9	8.0	6.5	9.8
Iron (Fe)	.03	.33	.03	.16	.08	.05
Calcium (Ca)	18.	104.	9.2	3.6	1.1	18.
Magnesium (Mg)	2.9	44.	2.7	.9	.5	2.1
Sodium (Na)	2.0	1245.	1.5	.9	1.3	1.0
Potassium (K)	1.8	26.	.8	.6	.7	.9
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	69.	593.	39.	14.	2.4	38.
Sulphate radicle (SO_4)	3.0	324.	2.8	1.8	.8	5.1
Chloride radicle (Cl)	1.8	1764.	1.0	.9	2.0	2.6
Nitrate radicle (NO_3)	.91	1.0	Trace	Trace	2.9	1.3
Total dissolved solids at 180° C.	75.	a3857.	45.	26.	b20.	56.
Total hardness as ($CaCO_3$c)	57.	440.	34.	13.	5.	41.
Date of collection	April 9, 1921	April 9, 1921	April 15, 1921	April 15, 1921	April 15, 1921	May 12, 1921

a Hydrogen sulphide (H_2S) 104 parts per million.

b Free carbon dioxide (CO_2) 37 parts per million.

c Computed.

1. Town spring at Iron City.

2. Eight-inch drilled well, 315 feet deep, of Seavy & Lull, Iron City. Water for analysis obtained from depth of 200 feet.

3. Dunn's Spring, municipal supply, Collinwood.

4. Shanatee Creek, 3 miles east of Collinwood.

5. Eleven-inch drilled well (No 8), 275 feet deep, of the Tennessee Charcoal Iron Company, Collinwood.

6. Spring of Bon Air Coal & Iron Corporation, about 100 feet northwest of railroad station, Allens Creek, (Post Office, Ruppertown).

NOTES ON SPRINGS

A few of the springs have been described under the above heading "Town supplies." Notes on a number of others are given below.

Blowing Spring, which is on Blowing Spring Branch, issues from a small opening in the Brassfield limestone. If this opening could be entered it would be found to run some distance into the hill. The spring, as would be inferred from its name, is so named from the fact that air rushes in or blows out of it at times. When it was visited on October 9, 1913, the current of air coming from it was strong enough to produce motion in weeds for a distance of 20 feet away from the spring.

The Hughes Spring, which is in Hughes Hollow 2 miles south of Clifton, is a large spring. It issues from the Decatur limestone. The Marion Furnace, a charcoal iron furnace, which was operated before the Civil War was located near it.

A fine spring occurs near the schoolhouse which is on Eagle Creek near the west border of the quadrangle. Another fine spring issues in a cave on Flat Gap Creek at the west border of the quadrangle.

A spring which is on Factory Creek near the mouth of Couch Branch forms a picturesque waterfall 15 feet or more high.

Several springs including both iron and iron-free springs occur at and near West Point and Pinkney.

A spring with a large flow is on the W. F. Williams place which is on the west side of Holly Creek 1 mile north of Corning. It issues at the base of a hill in which the Fort Payne chert occurs. The water is soft and a few bubbles of gas which may be carbon dioxide rise to the surface at times.

On Pinhook Branch about half way between Iron City and St. Joseph there is a spring with a strong flow which issues high on the hillslope and the water in running down the slope falls over a series of rock ledges and thus forms a beautiful cascade.

A fine spring at Powell's Mill has a flow of about 7.5 gallons per second.

Numerous strong springs which are said to have a regular flow issue at the base of the Tuscaloosa gravel along Cypress Creek between Cypress Inn and Whitten's Stand. The base of the gravel along this stream is marked by the outcrops of conglomerate which consists of pebbles that have been cemented together by iron oxide.

DISCHARGE AND GRADIENT OF STREAMS

There are many streams in the quadrangle with a fall of 40 to 50 feet which would give one-half to one horsepower or more within a mile of their headwaters. The streams as a rule do not gain volume very fast except within the first 2 miles of their courses. This is due to the facts that they flow over rock ledges or thin deposits of gravel and finer material along their upper courses and that their lower courses are in thick gravel beds into which much of the water sinks. In several places water power for farm use could be obtained from some of the small streams near their headwaters. As pointed out by Warren R. King in the next chapter, nearly all of the larger streams have sufficient, though not great, fall for them to furnish power for commercial purposes. Several grist and saw mills are run by water power, but their number is not as great as it formerly was. Water power was used in the operation of Van Leer Furnace which was located on Butler Creek 2½ miles west-southwest of Iron City, of Wayne Furnace which was located on Furnace Branch, 5 miles north of east of Waynesboro, and of Fortyeight Forge, which was located on Fortyeight Creek one mile south of the bridge on the Waynesboro-Lawrenceburg Road.

The measurements of the discharge of several streams are given below. They were made during May, June and August, 1913, when the streams were very low owing to an unusually dry season. They therefore probably represent the minimum discharge of these streams. All of the measurements except when so stated were made by N. F. Drake by means of a weir.

An approximate measurement (August, 1913) of the flow of Forty-eight Creek near the bridge on the Waynesboro-Lawrenceburg Road gave 4 second-feet. The entire flow at that time was somewhat greater as there was a seepage through the gravel in the stream bed.

The flow of Little Fortyeight Creek about 2½ miles above its mouth was determined in August, 1913, to be about one second-foot. The measurement was made where the stream flows over ledges of the Hardin sandstone.

Discharge measurements of Buffalo River were made on August 6, 1913, about three-fourths of a mile above the mouth of Green River, by N. F. Drake, Bruce Wade, Olaf P. Jenkins and the writer. A computation by the writer of these measurements shows that the discharge was about 140 second-feet.

The flow of Green River was measured on August 5, 1913, at a point about 1 mile above its mouth. The flow over a weir was 3.6 second-feet but there was some water running through the gravel below and on either side of the weir. The total flow is perhaps 5 second-feet. This amount of flow with a 30-foot fall which could apparently be obtained here would give about 19.6 horsepower.

The flow of Buck Branch, a tributary of Green River, as determined on August 9, 1913, about half a mile above its mouth was found to be .14 of second-foot. This amount of flow over a 50-foot fall which could be obtained at this locality would give .6 of a horsepower.

A test of the flow of Barlow Branch which is just northeast of Waynesboro was made near its mouth on August 4, 1913, and showed its flow to be one-twelfth of a second-foot.

The flow of Hurricane Creek about 2 miles above the mouth of Barlow Branch was determined by a weir on August 4, 1913 to be .62 of a second-foot. A similar test which was made on this stream about one-fourth mile above the mouth of Barlow Branch showed a flow of only .29 of second-foot. The difference in the two measurements is due to the seepage of much water through gravel in the stream bed at the last-named place.

The flow of water over a waterfall, about 40 feet high, on Falls Branch which is a few miles northwest of Collinwood, was measured late in June, 1913, by E. L. Lull and J. C. Lawrence and found to be 600 gallons per minute which is equivalent to 1.3 second-feet.

A measurement of the flow of Indian Creek was made in August, 1913, at a locality 2½ miles north-northwest of Victory and gave 5.2

second-feet which does not of course include the considerable amount of seepage through the gravel.

The discharge of Shoal Creek at Iron City below the mouth of Hollow Creek was measured late in May, 1913, by E. L. Lull and was found to be 140 second-feet.

The flow of Grass Creek in the southwest corner of the quadrangle just above its junction with Second Creek was determined (August 30, 1913) by a weir to be 1.4 second-feet, but if the seepage through the gravel be added to this the entire flow would be some greater. The flow of Second Creek above the mouth of Grass Creek was measured by a weir on August 30, 1913 and found to be 1 second-foot. This of course does not include the seepage through the gravel below and on either side of the weir.

WATER POWER POSSIBILITIES

BY WARREN R. KING OF THE U. S. GEOLOGICAL SURVEY

GENERAL FEATURES

The Waynesboro quadrangle lies wholly in the Tennessee River water shed. From a point near the center of the quadrangle, the drainage is in three directions, viz., north, south and west. The elevation of the top of the main dividing ridge varies from 950 to 1,075 feet and its general direction is northeast and southwest. The principal stream is Buffalo River, which flows from east to west across two-thirds of the northern part.

Little Buffalo River, Fortyeight Creek and Green River flow north into the Buffalo River. Beech Creek, Hardin Creek and Indian Creek flow west into Tennessee River; and Second Creek, Cypress Creek and Shoal Creek flow south to Tennessee River.

The descent of the streams is abrupt to an elevation of about 750 feet above sea level and thereafter the fall to the borders of the quadrangle ranges from 10 to 25 feet per mile with an average of about 15 feet per mile. It will thus be seen that at almost any point along any of these streams a very appreciable head may be gained in a comparatively short distance and one of the two essentials for water power development is easily satisfied.

With the exception of Buffalo River all streams within this area have their source here, consequently they are small and nothing in the way of major power developments is possible unless storage is provided. There are of course numerous small water power possibilities adequate for local uses, but for the purpose of this report, only such developments as seem to be of commercial importance will be considered, and a lower limit of 1,000 horsepower has been arbitarily set. Without ample storage the minimum flow of all of these streams is such as to render

them useless for commercial power. It will be seen from the topographic map (Plate I, in pocket) that these streams are very well adapted to storage, although, usually where this is the case, the land damage must necessarily be heavy, due to the large amount of valley lands which will be submerged. Such lands afford most of the good tillable soil in the quadrangle. The feasibility of such power project therefore, is not only determined by construction and operating costs, but in a large measure by the amount of flowage damages.

The quadrangle is largely forested and soil conditions are such as to produce a much better distribution of runoff than is to be found from many of the neighboring streams where this is not the case.

The average yearly rainfall throughout this section is about 50 inches, varying between 38 and 62 inches or about 25 per cent either way from the mean.

As a basis for computations a number of damsites have been selected by inspection of the topographic map and drainage areas and reservoir areas measured with a planimeter. Due to the large contour interval and the small scale of this map (1 inch=2 miles) these computations and quantities are only roughly approximate, though it is believed they are sufficiently accurate to give a good idea of the possibilities for water-power in this region.

Certain terms are used herein which need some explanation in order that they may be better understood by the average reader. One cubic foot per second (or one second-foot) is a unit of flow and is the equivalent of 448 gallons per minute. One acre-foot of water is a storage or quantity term which means an acre covered to the depth of 1 foot. In computing the horsepower the formula $\frac{Q \times H}{11}$ was used, in which "Q" is the quantity of water in cubic feet per second and "H" is the effective head on the water wheels. This gives the possible horsepower, assuming 80 per cent efficiency of water wheels. It is further assumed that complete regulation of a stream can be obtained by providing storage capacity sufficient to hold one-half the annual runoff. The truth of this assumption can not be determined without a more complete knowledge of the stream flow, but this provision would seem to be ample and well on the safe side. No allowances are made for evaporation or for regulating losses.

Until very recently no attempt has ever been made to determine the runoff of streams in this section, and as yet data of this nature are too meager to be of any real value. Therefore, such assumptions as are adopted herein regarding streamflow may be vastly in error. A correct statement in this connection is possible only after actual records of flow are obtained covering a term of years. A few measurements of the flows of the streams by N. F. Drake, H. D. Miser, and others are given on pages 157 to 159.

In cooperation with the State of Tennessee, the U. S. Geological Survey established a gaging station on Buffalo River at Flatwoods on May 29, 1920, and a continuous gage-height record has been obtained since that date. Due to the excessive cost and inaccessibility of the place only 4 discharge measurements have been made which by no means cover the range of either high or low water seasons.

These short records of streamflow at Flatwoods and similar short records at the following additional stations in middle Tennessee are taken as a basis in computing available water power: Duck River at Columbia; Duck River at Centerville; Harpeth River at Bellevue; and Red River at Adams. It is estimated that the mean minimum flow throughout this area is 0.1 cubic foot of water per second per square mile of drainage area; that the average flow for the lowest month of the year will be 0.25 cubic foot per second per square mile of drainage area; that the average flow for the lowest 6 months will be 0.5 cubic foot per second per square mile; and that the average flow for the year is 1.50 cubic feet per second per square mile. In other words, if a stream has a drainage area of 100 square miles the minimum flow would be 10 cubic feet per second; the average flow for the lowest month would be 25 cubic feet per second; the average flow for the lowest six months would be 50 cubic feet per second; the average flow for the lowest 9 months would be 100 cubic feet per second; and the average flow throughout the year would 150 cubic feet per second.

In taking up the matter of water powers of this district the Buffalo River is the most important and hence will be considered first.

Buffalo River

The drainage area of the Buffalo River above the point where it crosses the Wayne-Perry County line is about 450 square miles. The only possible major water water site in the district is located near this point, and by utilizing the storage capacity created by construction of a dam at the powersite, there appears to be a possibility of developing about 16,900 continuous horsepower. This development would consist of a dam 110 feet high, located just below the county line. The upper 25 feet of this dam would provide storage whereby complete regulation of the river could be effected and a constant flow of 675 cubic feet per second could be maintained throughout the year. The pool created when the reservoir is full would cover about 11,000 acres of valley land and would extend to the Nashville, Chattanooga & St. Louis Railway bridge at Riverside, approximately 25 miles upstream. From the intake 25 feet below the crest of the dam the water could be carried, by means of a tunnel and flume, or pipe line, about 8 miles long, to the power house which would be located near Peters Landing on Tennessee River. In this way a total head of about 275 feet would be obtained, which with

the above flow should yield in the neighborhood of 16,900 continuous H. P. It might prove more economical to take the water through a short tunnel into the Beech Creek drainage and utilize it through two or three power houses along this creek instead of at a single plant at Tennessee River.

While this development is physically possible, it is doubtful whether the expense involved would be justified, on account of the large acreage of bottom land which would be submerged. If we assume that $200 per horsepower is an allowable cost unit, this development would warrant an expenditure of about $3,400,000. The feasibility of such a project can be determined only after careful plans and estimates of cost are prepared.

At a point called Voorhies, 3 miles east of Riverside, there appears to be another damsite worthy of consideration. This is just below the mouth of Little Buffalo River. The drainage area above this point is about 225 square miles, hence the minimum discharge would be 22.5 second-feet, the mean for the lowest month would be 56 second-feet, the average flow for the lowest 6 months period would be 112 second-feet, and the mean for the year 338 second-feet.

Assuming a dam 85 feet in height with no allowance for storage, the possible power during minimum flow would be about 174 horsepower. About 6 square miles of land would be submerged by construction of this dam.

With a 10-foot drawdown of the pond 36,500 acre-feet of storage water would be provided and the minimum flow could be maintained at 160 second-feet, equivalent to 1,090 horsepower.

If, however, a 35-foot drawdown were utilized the entire flow of the river, amounting to 250,000 acre-feet, could be regulated to a constant flow of 338 second-feet, in which case 1,540 horsepower would be available.

Economy in development would prove which of the above projects is better. Land damages would be proportionately lower at Voorhies than at Flatwoods, as would construction costs, due to the close location to railway transportation. The two projects might well be considered together as in this way practically the entire potential water power of Buffalo River could be realized.

These two examples are cited as possibilities and may or may not be the best means of utilizing the potential energy of this stream. Properly conserved the stream flow and fall are sufficient to develop 18,400 continuous horsepower at these points.

There are of course other opportunities for the development of small water powers on Green River, Fortyeight Creek and other minor tributaries but in general, these would be sufficient for small mill power only and not of commercial importance.

Hardin Creek

The drainage area of Hardin Creek below the mouth of Eagle Creek is 78.5 square miles. The minimum flow would therefore be about 8 second-feet, the average flow for the 6 low-water months would be about 40 second-feet and the mean annual flow about 120 second-feet. A dam 100 feet high located below the mouth of Eagle Creek would flood about 4.4 square miles. If the upper 15 feet were utilized for storage the entire runoff of the stream could be regulated to a constant flow of 120 second-feet. A very short tunnel would carry this water through the ridge to the Clifton side and a power house located at the Tennessee River at that place would make possible a head of 135 feet. Under these conditions 1,470 horsepower could be developed.

Indian Creek

The drainage area of Indian Creek about Weatherford Creek is 133 square miles. The minimum flow would be 13 second-feet and the mean annual flow would be about 200 second-feet. A dam 100 feet high at this point would flood about 3,600 acres of land. The upper 20 feet would regulate the entire annual flow, amounting to about 146,000 acre-feet. The head would vary from 100 to 80 feet and the minimum power available would be 1,450 horsepower. Below this point, Indian Creek has a fall of nearly 150 feet before reaching Tennessee River. If the water after passing through the power house described above, would enter a pipe line and be conveyed to a point above Tennessee River, a distance of about 15 miles, the same water could be used to develop 2,720 additional horsepower under a 150-foot head.

Shoal Creek

No topographic map of the upper end of Shoal Creek is available and in the absence of such a map, estimates of the power possibilities here are less reliable than for those streams which have thus far been considered. There appears to be a good damsite on this stream about one mile above the mouth of Factory Creek. The drainage area above this point is roughly about 210 square miles which should yield a minimum flow of 21 second-feet and a mean flow for the year of 315 second-feet. Judging the nature of this valley to be similar to the other streams in this district it seems probable that with a dam 80 feet high, the upper 30 feet being allowed for storage, the stream could be completely controlled and a constant flow of 315 second-feet obtained. This quantity of water used under the remaining 50-foot head would produce approximately 1,430 horsepower. The area which would be submerged would probably be about 3,500 acres. This site is only of passing interest as its location is so close to Muscle Shoals on Tennessee River in Alabama as to render its development inadvisable, at least for many years to come.

Summary

The following table gives a summary of the water power possibilities outlined above:

Plant No.	Streams	Location	Height of dam	Acres flooded	Continuous horsepower
			Feet	Acres	
1	Buffalo River	Flatwoods	110	11000	16900
2	Buffalo River	Riverside	80	3800	1540
3	Hardin Creek	Below Eagle Creek	100	2800	1470
4	Indian Creek	Below Weatherford Creek	100	3600	1450
5	Indian Creek	Mouth	(a)	....	2720
6	Shoal Creek	Above Factory Creek	80	3500	1430
					25510

*a*Pipe line 15 miles long.

The principal value of the sites on Hardin and Indian creeks lies in their nearness to the larger Buffalo River site and their consequent use in securing regulation and in sustaining the peaks in the power demand, once the capacity of the main plant has been reached. The figures given in the table represent continuous horsepower but it must be understood that many times that amount of power could be produced for a sufficient period to carry the demand peaks if adequate wheel and generator capacity were installed, and the plant were used only for that purpose. The recent improvements in automatic control of small plants may make these sites, of relatively small capacity, feasible of development.

Naturally the success of any power project depends primarily upon a suitable market for the product. The proximity of the Muscle Shoals site on Tennessee River which is situated only a few miles from the southern border of the quadrangle will doubtless have a controlling effect on the development of other sites in the vicinity until the full output of the Muscle Shoals site has been utilized, but thereafter the availability of transmission lines will probably promote the development of small sites which by themselves would not warrant the construction costs involved in use in distant power markets.

There is a marked tendency at this time toward interconnection of all sources of power within a given district, and it is entirely probable that all of the large power plants in southern Virginia, North Carolina, Georgia, Tennessee, Alabama and possibly Kentucky will ultimately be tied together in one large transmission system, which will deliver electrical energy to all important centers within that territory. Through such interconnection a higher load factor is obtained and better and cheaper service is accomplished. Nearly the whole of the State of California is now linked up by a system of this kind, with the further likelihood of its being extended to connect with existing power systems in Oregon and

Washington. The same thing is contemplated in the north Atlantic States.

The sites outlined in this report are favorably located to furnish hydro-electric power to a large number of cities and towns in west and middle Tennessee, a region which is relatively poor in this respect, and for that reason appear to warrant more detailed investigation.

A transmission line 55 miles in length would supply all industrial and lighting requirements of Clifton, Decaturville, Darden, Lexington, Jackson, and intervening towns. From Jackson branch lines might be run to Humboldt, Trenton, and Milan, and to Brownsville. Thus with transmission lines a little more than 100 miles in length, nearly every city and town in western Tennessee might well be served.

Memphis and Nashville are within transmission distance but will likely derive power from Muscle Shoals when that project is completed and are therefore not considered as a probable market for power generated in the Waynesboro district.

The energy which could be generated at the plant on the Buffalo River near Riverside could be used at Allens Creek, Hohenwald, Centerville, Mount Pleasant and Columbia.

Doubtless the present demand from all of these places would fall a great deal short of the 24,000 horsepower (exclusive of Shoal Creek) which could be generated at these plants, but if the larger development were built first the other units could be added as the demand increased.

Taken together it will be seen that the water power resources of this section may be of real commercial importance, and might well be a large factor in the future industrial growth and expansion of this portion of the State.

IRRIGATION

Most of the streams are perennial and the water for them is supplied by springs through the greater part of the year. The flow of many streams is greater near their headwaters than along other parts of their courses where much of the water flows below the surface in thick gravel beds.

The occurrence of springs at the heads of the valleys and on the hill slopes favors the use of their water for irrigating the land in the valleys. While in most cases the water supply is not sufficient for extensive irrigation tracts it is sufficient for a great number of small scattered areas along the valleys where the largest springs occur. Such irrigation would be especially adapted to gardening and farming on a small scale. By using these waters for irrigation the small valleys would never suffer from droughts, and farming and gardening in them would always be profitable.

SOILS

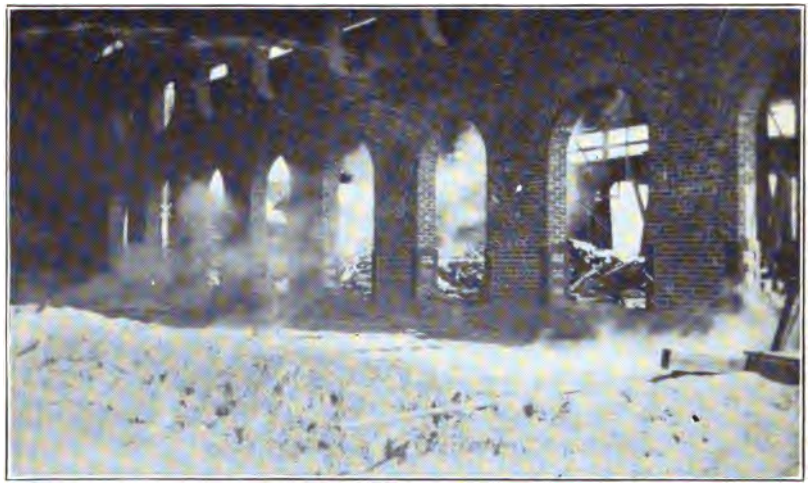
The surface of most of the Waynesboro quadrangle is rough and consists of flatwood regions or uplands, of numerous irregular narrow ridges and of terraces and flats along the larger and most of the smaller streams. Only a relatively small portion—perhaps 20 to 25 per cent—of the quadrangle has been cleared and put under cultivation. Most of the valley lands have however been cleared and some tracts on the hill slopes and on the uplands have been cleared and put under cultivation.

The terraces and stream flats are especially adapted for general farming; the hill slopes are suitable for grazing and general crops; the uplands are suitable for general farming; and they and the hill slopes are especially adapted to fruit culture, though some fruit is grown in the valleys. The chief farm products are corn, cotton, wheat, peanuts, hay, and live stock.

The terraces occur as patches here and there at elevations of as much as 140 feet above the present streams. Practically all of them are along Tennessee and Buffalo rivers. The most conspicuous of these is the one on which the village of Flatwoods is located. The stream flats are as much as half a mile wide and, as previously stated, occur along the larger and most of the smaller streams. The soil of the terraces and stream flats consists of a brown loam to an average depth of 12 inches. The subsoil is similar in texture to the soil and is yellowish to light brown in color, but is more compact than the soil. At a depth of 2 feet or more a bed of angular fragments and well-rounded pebbles of chert is usually found, but at many places, these fragments and pebbles occur in large quantity in the soil and subsoil. The soil is fertile and affords most of the tillable land of the quadrangle. It has always been considered very desirable land for general farming. The stream bottoms were the first lands to be cleared, and many fields therefore have been under cultivation for 50 years or more. Good moisture conditions prevail at most places and crops at such places do not suffer greatly during droughts. Because of the fertility of the soil and of the accessibility of water in the valleys most of the inhabitants of the quadrangle live in the valleys. Collinwood and St. Joseph are the only towns of any size that are located on high uplands.

The soil of the flatwoods regions or uplands, of which there are large areas at and near St. Joseph, Ovilla, and Collinwood, is a gray loam varying from a few inches to 2 feet in depth and is underlain by yellow to red clays but in much of the southwest quarter of the quadrangle it is underlain by sand. This soil at many places contains pebbles in both small and large numbers and at some places contains chert fragments. The soil on the narrow ridges contains more pebbles and chert fragments than it does on the broad ridges and uplands. This soil

(A) 50,000 cords of chemical wood. The waste of lumbering. For use by Wayne Woods Product Co., Collinwood, Tenn.



(B) Charcoal Pig Iron Furnace, Tennessee Charcoal Iron Company, Collinwood, Tenn.

although not fertile is made to produce well. It is light and sandy, easily cultivated, and responds readily to the use of fertilizers.

The narrow ridges cover most of the quadrangle; their slopes are steep; and the slopes and crests are covered with a thin coating of soil. The soil probably averages less than a foot thick and a small fraction of it to more than half of it consists of chert fragments or pebbles or both. The soil is derived from any rock formations but mostly from the Fort Payne chert, St. Louis limestone and Tuscaloosa gravel. The lower slopes are the more productive and the moisture conditions are better on the lower slopes than on the upper. A difference in the productivity is recognized in the direction of the slopes, the northern slopes being preferred. With the prevailing methods of cultivation the soils of the hill slopes soon wash away and the surface is deeply cut by heavy rain falls, washing down not only the soil, but subsoil and underlying gravel and rock fragments. These gravels lodge in the valley streams causing them, during freshets, to overflow and wash away the valley soils. The seriousness of this loss, or double loss, is apparent when one remembers that the soil once washed away is gone forever. The hill slopes should be kept for the growth of forests or if cleared should be used as grazing lands.

The comparatively large areas over which the limestones of Silurian and Ordovician age are exposed in the northwest corner of the quadrangle have a good soil in the fairly level areas and on the gentle hill slopes. The soil is underlain by red clay and generally contains fragments of limestone and chert; and numerous ledges of limestone protrude through it at many places. These areas are rolling and the slopes range from gentle to steep. Many small areas on the hill slopes have no soil and are known as glades.

FORESTS

The Waynesboro quadrangle is densely forested except for the relatively small portion—perhaps 20 to 25 per cent of the quadrangle—that has been cleared and put under cultivation.

The valley lands and hill slopes are nearly everywhere fertile and support a luxuriant growth of trees, where the forest has not been disturbed. Most of the valley lands have however been cleared and considerable areas of the hill slopes and of the crests have been cleared and put under cultivation. When the hill slopes are cultivated not only their soil but much of the subsoil and the underlying gravel and rock fragments soon wash away. They should be kept for the growth of forests or if cleared should be used as grazing lands. The forests have been and are one of the best assets of the Waynesboro quadrangle and with proper care they will continue to be of great value.

The kinds of trees are numerous. The six most important commercial kinds are oak, poplar, hickory, cedar, chestnut, and yellow pine, of

which oak is the most important. The prevailing trees on the crests of the hills and ridges are black oak, chestnut, oak, pine, white oak, and hickory and those on the hill slopes and in the valleys are black oak, white oak, chestnut, chestnut oak, poplar, hickory, beech, sycamore, walnut, sweet gum, maple, cedar, and elm. Some of the timber is virgin but most of it is second growth. The timber was removed many years ago from large areas for use in iron furnaces at Allens Creek, in Wayne Furnace on Furnace Branch, and in Van Leer Furnace on Butler Creek, but such areas have rapidly been reforested and those that were completely cleared 40 or more years ago are now covered with trees at least several inches in diameter. In 1918, 68,000 cords of hard wood were cut on the 85,000-acre tract of the Tennessee Charcoal Iron Co. for use in the plant of the Wayne Wood Products Co. at Collinwood. A description of this plant will be given later. Lumber mills including stave mills, spoke factories, planing mills, and saw mills, are numerous. Besides lumber large quantities of railroad ties, fence posts, and telegraph and telephone poles are shipped.

The uses for the different kinds of trees are here named. All varieties of trees are used for fuel but only the hard woods are used for making charcoal, tar, calcium acetate, and wood alcohol. For first-class ties honey locust, walnut, white oak, tan oak (chestnut oak), sassafras, mulberry, cherry, slippery elm, and black locust are used; for soft wood ties black oak, water oak, chestnut, yellow pine, red elm, sweet gum, black gum, yellow poplar, beech, sugar maple, ash, and persimmon are used; for telephone and telegraph poles chestnut and red cedar are used; for lumber yellow pine, yellow poplar, white oak, black oak, chestnut oak, cypress, and walnut are used; for spokes hickory and white oak are used; for barrel staves white oak is used; for fence posts red cedar, honey locust, black locust, and white oak are used; and for barrel hoops hickory saplings are used.

The chestnut (tan) oak was formerly used in tanning leather which then was one of the important industries of this part of Tennessee. Concerning this industry in Wayne County the following statements were made by J. B. Killebrew and J. M. Safford[1] in 1874:

"Previous to the war, Wayne County was noted for the number and excellence of its tanneries. More than a dozen were then in operation, manufacturing annually 200,000 pounds of superior leather. Many of them were abandoned or destroyed during the war, and now the number is reduced to four. These manufacture 100,000 pounds of leather annually. The hides are obtained in the St. Louis and New Orleans markets. The leather is mostly shipped to St. Louis. With the abundance of streams that thread the county, and the almost exhaustless quantities of tan-bark, the manufacture of leather will doubtless become in the future one of the leading industries of its citizens. Bark is sometimes shipped, though not in large quantities."

[1]Killebrew, J. B., and Safford, J. M., Introduction to the resources of Tennessee, p. 977, Nashville, Tenn., 1874.

A chemical plant for the manufacture of crude wood alcohol was erected at Collinwood during the war at a cost of several million dollars, and is being operated by the Wayne Wood Products Co. Wood for the plant is being obtained from the 85,000-acre tract of the Tennessee Charcoal Iron Co. in Wayne County. Estimates based on careful cruising show, according to R. W. Durrett, General Manager of these two companies, that there are between 300,000,000 and 400,000,000 feet of merchantable timber and about 2,000,000 cords of wood on the tract. In 1918, 68,000 cords of wood composed of hard woods of different kinds were cut on this tract but only a small fraction of it had been used before April, 1920. Besides wood alcohol the products of the plant include tar, calcium acetate, and charcoal. Some of the charcoal has been shipped but beginning in 1920 it has been used in the blast furnace (Anna Furnace) at Collinwood.

The wood products plant is owned by the Wayne Wood Products Co. and consists of two units, a carbonizing plant and a distillation plant. It in reality forms a part of a large composite plant of which the other two parts are a band mill for the manufacture of lumber and a 100-ton charcoal iron furnace, known as Anna Furnace. The band mill and furnace are owned and operated by the Tennessee Charcoal Iron Co. The following description of the composite plant has been kindly prepared by R. W. Durrett, under the direction of Thomas S. Bailie, President of the Wayne Wood Products Co.

"The carbonizing plant consists of twenty 10-cord capacity, standard gauge retorts which are set in batteries of pairs, with the necessary condensers, and with gas and liquor lines for the recovery of the volatile products resulting from the carbonization of the wood. This equipment is housed in a brick and steel building with an asbestos board roof. A fan-shaped arrangement of tracks serves the retorts on the charging side of the plant; and on the pulling side of the plant beyond the coolers,—two of which are spaced in line with each retort—there is an electrically driven transfer table that is used for transferring the carbonized charges from the retorts to the coolers, and for finally transferring the charges to a storage bin for use in the blast furnace.

"For carbonizing, dry 4-foot cordwood is packed in 2½-cord close-slatted steel cars. A charge which consists of four such cars loaded with wood is switched to the track that runs into each retort. The storm doors inclosing the ends of the settings are opened, then the retort doors are opened, and, after the charge is run in, the doors are closed and made tight by tapered keys which are driven into pockets in lugs around the door frames. Fires are started on the grates that are provided in each end of the settings which are under each retort; and when the brickwork of the arches under the retorts has begun to heat, a portion of the tar (known as "soluble tar") from a previous operation is sprayed by means of steam jets into the fires boxes. This tar with the non-condensible gases from the retorts themselves, provides almost sufficient fuel to bring about the carbonization. The deficiency in fuel is made up by using saw mill refuse or the cheaper grades of coal. Carbonization is effected at comparatively low and carefully regulated temperatures for best results. The arches, flues, and baffles of the settings are arranged to give a uniform distribution of heat to the retort and a long passage of the hot products of combustion from the grates for the absorption of as much heat as possible by the brickwork and retort. The settings are

provided with peep holes for observing the condition of the fires and the bottoms and sides of the retorts, and are provided with dampers for the regulation of the draft. The retorts are equipped with indicating and recording pyrometers for the control of the temperature of gases inside them. Each retort is fitted with two large tubular water-cooled condensers through the tubes of which the gasses are passed. The condensible constituents are knocked down here to a liquid known as crude pyroligneous acid, what is sometimes sold under the trade name of "liquid smoke." Branch lines run from the condensers to a main line. These lines convey this acid and the insoluble tar, which is produced mainly in the latter stages of carbonization, to storage tanks from which they are pumped to a battery of storage and settling tanks to await further treatment in the distillation plant.

"Carbonization of the wood is effected in 24 hours, after which the doors are opened and the carbonized charge is withdrawn into the first cooler by means of a cable that runs from a drum on the transfer car. After this a locomotive runs a fresh charge of wood into the retort, the doors of the cooler and of the retort are then quickly closed and the other retorts are pulled and charged in like manner. This operation is conducted rapidly to avoid long exposure of the hot charcoal to the atmosphere and to conserve the heat of the retort and of the setting as much as possible for the incoming charge. On the following day, the operation of pulling and charging is repeated, and the charcoal in the coolers is moved ahead to make room for that coming out of the retorts. After the charcoal is thus cooled for 48 hours out of contact with the open air, it is allowed to stand outside for 24 hours before it is transferred to a ferro-concrete storage bin for use in the blast furnace.

"The storage and settling tanks for the crude pyroligneous acid are connected and piped to permit not only the settling but also the drawing off of the insoluble tar. From the tanks the tar is passed on to apparatus where it is given special treatment for the production of pitch and wood-preserving preparations.

"The crude pyroligneous acid is now subjected to an evaporation in triple-effect vacuum evaporators for the removal of the soluble tar. Steam for making this evaporation is obtained from the exhaust of the blowing engines of the blast furnace and generator engines. This operation gives a tar-free solution of methyl alcohol and acetic acid. This solution passes into storage tanks which are arranged for the trapping and removal of the oils that are driven over by the evaporation in the triple effect. The soluble tar is concentrated in the third effect from which it is passed to tar stills for the recovery of the alcohol and acetic acid that have not been taken out at the low temperature in the third effect. This tar-still distillate is trapped for oils, is then combined with the oil-free solution from the triple-effect evaporation, and is next passed on to neutralizing tanks, where it is treated with well-slaked lime. The lime is slowly added until, after prolonged agitation, the solution is slightly alkaline in character. Agitation during and after the addition of lime is effected by means of paddle arms that are attached to a vertical shaft which revolves in the tank. The solution contains a natural indicator which shows a series of colors as different degrees of acidity are reached, but the end reaction that indicates neutrality is not sharp and can only be detected by experienced operators. An outside indicator is best used as a check on the operator. The lime that is used should be well slacked and derived from limestone with a very small percentage of magnesia.

"From the neutralizing tanks, the solution is pumped to settling tanks where it is allowed to stand long enough for the settling and the removal of suspended solid matter that results from impurities in the lime and for the settling and the removal of the organic matter that is precipitated while the solution is being changed from an acid to an alkaline condition. The settling or sludge is drawn off and put through a filter press to recover the solution it contains. This recovered solution is then re-

A

Tennessee Charcoal Iron Company Plant, Collinwood, Tenn.
(A) Wood Retort Buildings.
(B) Furnace and Chemical Buildings.

turned to storage and is next run through a continuous distilling apparatus for the recovery of the methyl alcohol. The alcohol from this operation is collected and stored in tank cars for shipment.

"After the removal of the alcohol in the continuous still the hot solution that contains the calcium acetate is put through another set of triple-effect evaporators where it is concentrated to about 16 degrees Baume. Exhaust steam is used to bring about this concentration. The concentrated acetate solution is pumped from the third effect to storage tanks, from which it is fed by gravity to rotary drum driers. The calcium acetate coming from the rotaries is a stiff paste about 50 per cent of which is moisture. From the driers it is carried by conveyors through a mixer which discharges the calcium acetate in the form of a very smooth paste into hoppers. From the hoppers the pasty acetate is picked up in the meshes of a wide woven-metal endless belt which travels slowly through the drier. An exhaust fan draws waste heat from the blast furnace stove stacks, through connecting mains, into and through the passes of the drier. The waste heat travels in the opposite direction to that in which the belt travels. The speed of the belt is timed, and the temperature and volume of the hot air are regulated so as to dry the acetate as the belt emerges from the last pass of the drier, where the dry acetate is shaken out of the meshes of the belt. The dry acetate is then discharged from the drier into a conveyor by which it is carried to a storage bin and then drawn from the bin in to sacks for shipment or storage.

"The carbonizing plant consumes 200 cords of wood per day and produces 10,000 bushels of charcoal and 40,000 to 45,000 gallons of crude pyroligneous acid per day. The apparatus and storage tanks of the distillation plant were designed to take care of this quantity of acid and produce 2,000 gallons of methyl alcohol and 40,000 pounds of dry acetate of lime per day.

"The charcoal is used in the blast furnace for smelting the brown iron ore from mines on the Tennessee Western R. R. If the iron ore deposits at and near Wayne Furnace are worked the ore from them will also be smelted in this furnace. The blast furnace gases are burned in stoves for heating the blast, and are also burned under the power plant boilers, which generate the steam that is required for power, distillation and other purposes. The blast furnace slag is utilized for road and street making and as ballast for railroad tracks.

"A large volume of cold water for condensing and other requirements is necessary and is obtained from deep wells and spring-fed streams near the plant. Centrally located boilers and a power house supply the steam and power that is required for operating the various units of the plant and for pumping the water used. A large and well equipped machine and repair shop for repairs and maintenance of equipment, as well as warehouses and store houses for supplies and products, have been provided.

"The general layout of the plant provides for the easy and economical handling of all materials used in the manufacture of the different products. The buildings are all of modern, fireproof, brick and steel construction, with steel sash and doors, and are well lighted and ventilated. This plant is the largest and most modern of its kind in the United States.

"The operation as a whole is an illustration of what can be done in the way of conservation, because the excess and waste products of one unit are utilized as valuable factors in another unit."

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